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Application and Operation of
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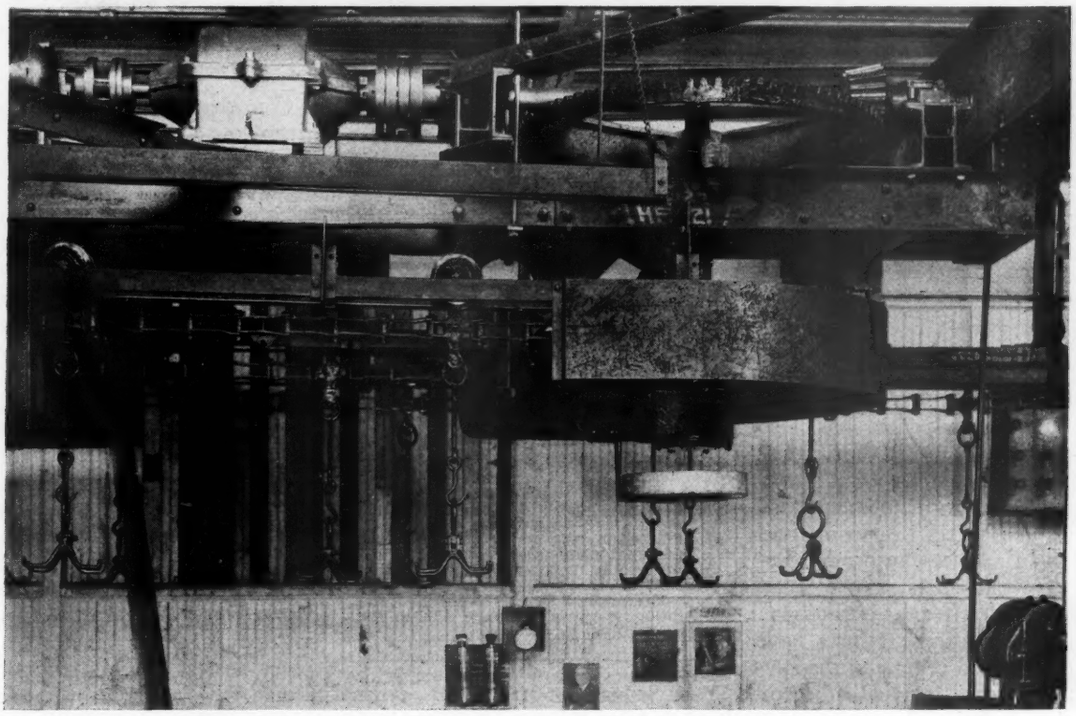


Crankshaft conveyor 2,560 ft. long in large automobile plant driven at 16 ft. per min. This conveyor has 11 horizontal and vertical turns. The reduction is obtained through a 142:1 Palmer Bee mill-type reducer, and a pair of bevel gears.

Trends in application of

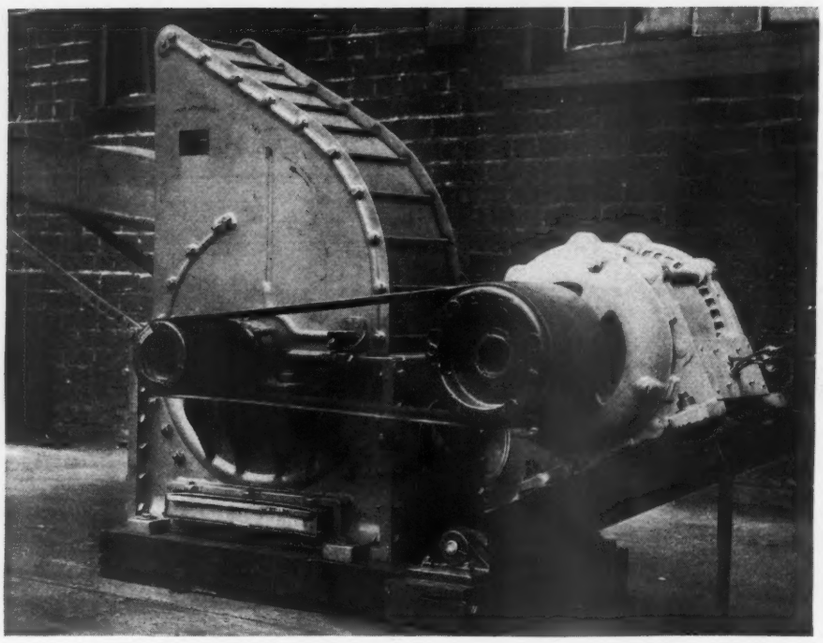
Power Drive Equipment

with details of recent improvements made in design

By FRANK E. GOODING
Associate Editor, Industrial Engineering

IT MIGHT truly be said that the importance of power transmission is just beginning to get full recognition among industrial operating men. When competition between industrial plants was not so keen as it is today, little attention was paid to power transmission problems. The entire cost of this item was small in comparison with many of the other expenses. Today, industrial competition, particularly in the older and well-established industries, has forced cost reductions in every phase of manufacturing and operation. The largest items of expense, labor and material, were attacked first, but many industrial plants are now delving into and reducing the lesser items of expense.

Power transmission and plant operation and maintenance costs have received particular attention, therefore, not only because of the possibilities of cost reduction but, also, because of the importance of providing reliable and continuous power service. Failure of a machine or its drive means interrupted production. Some plants, which have spent thousands of dollars in installing new machinery to improve production, but tried to save a few dollars on the drive or its control, have found that a production unit, like a chain, is no stronger than its weakest link. If the drive is improperly selected, installed, or maintained, or any part of it fails, the machine is put out of production.



A new development in short-center gravity belt drives applied to a hammer-type feed mill.

This Uni-Pull belt drive has just been announced by The Rockwood Manufacturing Co. Rockwood pulleys are used on the motor and driven pulleys to maintain a high coefficient of friction between belt and pulleys and the hinged motor mounting is so designed that gravity maintains the proper tension in the belt, according to the manufacturers. A more detailed description is given on page 498 in the New Equipment section.

Realization of the importance of continuous production has also brought about a change in the attitude towards general maintenance of power drives. As a result, maintenance has become a matter of inspection and prevention of failures by prompt detection of weak spots, rather than making repairs after a breakdown.

The results of these efforts have paid in dollars and cents and the savings made have applied directly toward the profits. The saving of a dollar in operating cost is equivalent to the addition of many dollars (depending upon the percentage of profit) of new or additional business.

Among the most noticeable efforts toward the reduction of production and operating costs have been the installation of newer and better types of equipment, with particular attention to the bearings and other wearing parts, as well as their lubrication. In addition, there has been a noticeable attempt to see that drives are properly loaded. Manufacturers of machinery usually recommend a powering that will be satisfactory for the heaviest load it is possible to place upon the machine; that is, they try to make the drive as strong as the machine. In case the machine is to be used for a variety of large and small work, it is always best to power it according to these recommendations. However, in many lines of manufacturing the machines will never be more than partially loaded. In such cases it is not only unwise but uneconomical to provide a large excess capacity in the drive. Accordingly, in many plants steps have been taken to measure the power consumption under normal load and provide a drive ample for the normal operating conditions.

The advantages of this plan are well shown in an installation where a study of the operating problems and power requirements indicated that a belt 1 in. narrower than the size originally recommended by the manufacturer could be used on an entire battery of machines. As this was a new installation the use of the narrower belt saved considerable in the cost of the original installation.

The close control which some operators keep over the drives under their supervision is well shown by the practice of one Chicago industrial plant. In this plant a large proportion of the machines are individually driven by motors of 10 hp. and larger. Whenever a new machine is placed in service a graphic meter is used to obtain the power consumption of the motor when disconnected, with the motor connected and the machine running idle, and when operating under load.

This record is filed away for reference and whenever that drive gives trouble a new record is made which shows almost at once whether additional load has been put on the machine or whether wear, or a defective gear or other mechanical part is responsible for the trouble. In this way, it is very easy to separate the motor from its drive and trace the cause of trouble. In many cases, troublesome drives are rather baffling because of the difficulty in locating the cause, particularly as the trouble frequently shows up in the motor when the cause lies in the machine or some of the mechanical elements of the drive.

Considerable study is also being given to power transmission and related problems by various interested manufacturing organizations and associated bodies. This should be of considerable benefit to industrial operating men. The constructive program that has just been undertaken by the American Gear Manufacturers' Association is one example of this. This organization, composed of gear manufacturers, has made extensive studies in the standardization of gears and investigations into gear-tooth loading and its effect on design, with particular attention to the non-metallic gear materials.

The Leather Belting Exchange has also done effective and important work over a period of years in making investigations on leather belt applications, as well as studies of belts which have resulted in improvements in their manufacture.

The American Engineering Standards Committee has begun investigations covering the establishment of standards which, although it may take considerable time for the full benefit to be obtained by industrial users, nevertheless, have extensive future possibilities for simplification of industrial drive problems. One of these investigations, for example, is a study of the possibility of standardizing the speed of the driven shaft on machines of various types. It is hoped that it will be possible to standardize these speeds, so that machines may be connected up much more easily. This organization, with the co-operation of interested societies and manufacturing associations, has also been working on standards for keyways, shaft sizes, standardization of motor frames, and other problems of far-reaching importance to industrial men.

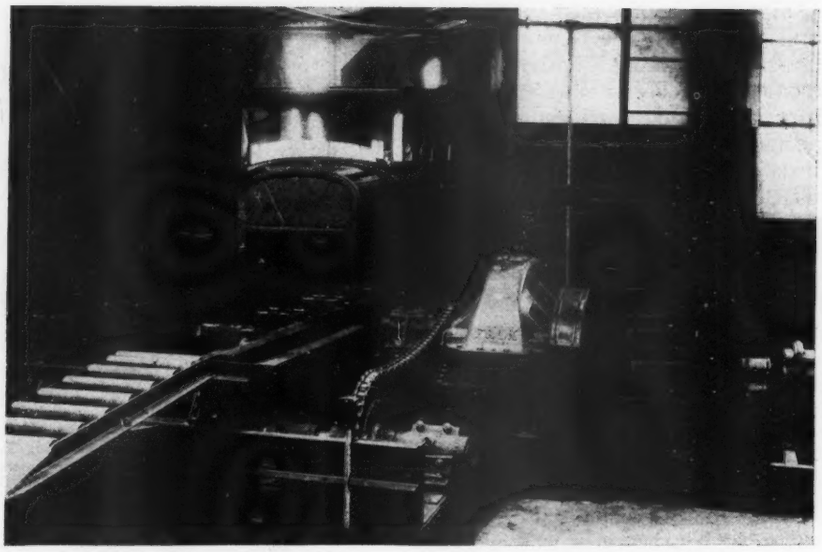
The recently organized Power Transmission Association, composed of manufacturers of power transmission equipment, is taking steps to provide similar valuable assistance to industrial operating men. One of the

most important of these services that has been announced will be the preparation of a Power Transmission Handbook to contain authentic and reliable data on the selection of power transmission equipment. This work will be carried on by a group of experienced engineers from various industrial plants and should be of great aid to industrial men.

Other trends and developments in power transmission activities will be discussed under their respective headings.

Group and Individual Drives—One of the important operating problems which is to be given considerable attention by the Power Transmission Association is the subject of the relationship and application of group and individual drives. These investigations will take up the subject of first cost, operating cost, convenience, reliability, and operating advantages and disadvantages. Operating men will welcome such an investigation.

During the past year several new plants have been laid out to operate largely on the group drive principle. This is exceedingly interesting because the tendency in these industries had been very strong toward individual drive. These isolated instances, however, can hardly be taken as a distinct trend. A recent example of a large group drive was the installation of an engine-driven lineshaft in a large, New York paper mill. Each of the 16 heaters in a group was connected to the lineshaft by a 14-in. belt. A 1,700-hp. compound-condensing engine drives this shaft through a 76-in., four-ply, Rhodes Tannate belt. This is probably one of the largest single group drives (from the standpoint of power transmitted) recently installed.



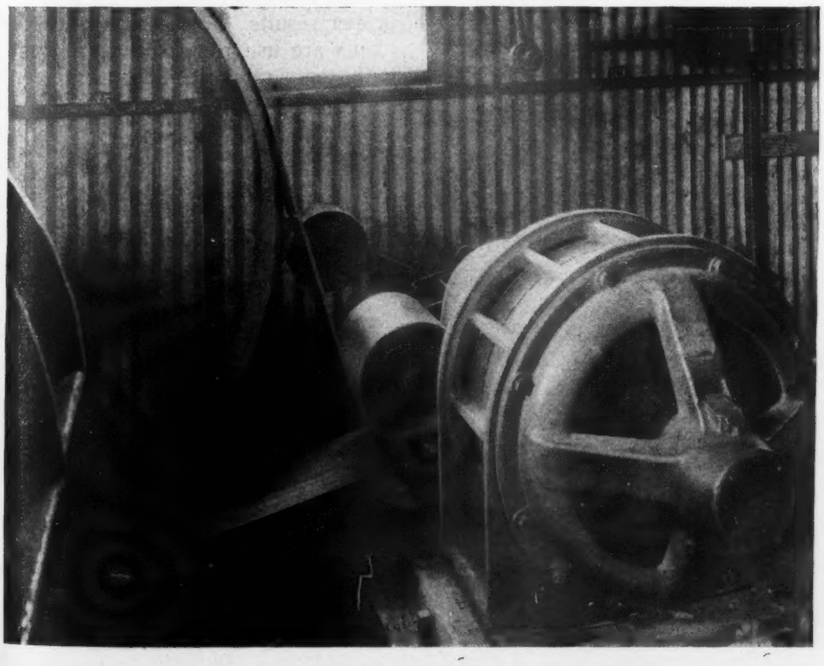
Body conveyor drive in new Pontiac automobile plant.

In this drive the motor is connected to a Reeves variable-speed transmission driving a Falk herringbone speed reducer with an outboard bearing carrying the sprocket for the roller chain connection to a shaft on the conveyor. This installation was made by Mechanical Handling Systems, Inc., Detroit, Mich.

Lineshafts—In the article, "Trends and Practices in the Use of Power Drive Equipment," which appeared in the October, 1926, issue of INDUSTRIAL ENGINEER, considerable attention was given to the tendency toward standardization of lineshaft sizes. This tendency has increased considerably during the past year, especially where plants have decided to install ball or roller bearings either on lineshaft hanger boxes or in pillow blocks. A standard shaft diameter is selected and all new shafts purchased accordingly, together with the standard bearings for the installation. In applying this standardization, there seems to be a tendency toward allowing rather ample rating of the standard shaft selected.

Flexible idlers are helping to solve many difficult drive problems.

Here a 40-hp. motor is driving a pulverizer on 5-ft. centers, using a Pulmax drive. The belt speed is 6,000 f.p.m. This is one of five pulverizers that were originally driven by open belts operating on 17-ft. centers. By changing the layout as shown here belt trouble has been reduced and the floor space formerly required by the drive has been greatly reduced.



Many times it is not realized, until too late, that it is a mistake to install lineshafts, hangers and bearings of the smallest possible size for the actual loading which will be placed on them at that time. Later, when rearrangement of the machines has forced pulleys midway between hangers or an additional machine load necessitates the transmission of larger amounts of power, it is discovered that the shaft can not handle the new requirements without excessive vibration. One instance was noted recently where in the interval between when the drive was laid out and the equipment received, sufficient additional equipment had been scheduled for the group to give the shaft an actual overload of 20 per cent. In case a shaft of ample size is to be loaded more heavily, it is a simple matter to install a larger motor. If the shaft is too small, however, the load must be cut down, re-arranged into smaller groups, or a new shaft installed.

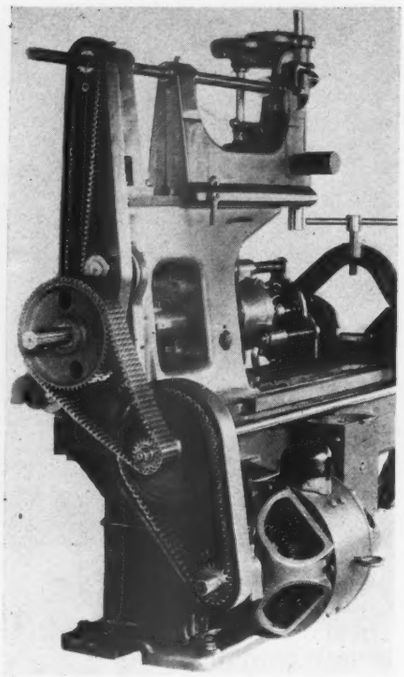
Most operating men understand and appreciate the importance of good millwrighting. Although false economy, it has been considered necessary in some cases to slight this important work to reduce the cost of installation. This skimping has usually taken the form of increasing the distance between hangers, inadequate bracing in the groundwork, or the use of too light a hanger.

Bearings—Studies of operating problems and causes of interruptions to service have indicated that one of the most vulnerable points on ordinary machines or other equipment lies in the bearings. Better lubricants and improved methods of applying them have had some effect in making bearings more reliable, but the older type of plain bearings were not designed so that effective use can be made of the better facilities for lubrication now available.

In the previously-mentioned analysis of power transmission developments, in the October, 1926, issue, the increasing use of anti-friction ball or roller bearings in lineshaft hanger boxes was emphasized. The past year has been marked by a growing tendency to use anti-friction bearings in different forms of power transmission equipment. This has been brought about largely by a recognition of the advantages obtainable through their use. Again, bearing engineers have successfully solved several problems in the application of such bearings to various types of power transmission equipment to which such application was formerly considered impracticable, for various reasons.

The net result of these factors has been a considerable increase in both the number and variety of applications to different types of power transmission equipment. These include gear drives of different kinds, and equipment used in connection with lineshafts, such as pillow blocks and shaft hangers.

In the modernization of industrial plants it has become common practice when rebuilding a machine or drive, to install pillow blocks with ball or roller bearings, particularly on the drive shaft. The use of these anti-friction bearing pillow blocks has accomplished much toward improving the operation of short shafts, jackshafts, and driveshafts which are a part of the machine. These bearings have better facilities for lubrication, which not only decreases the amount and, therefore, the cost of the lubricant but also the cost of its application and of the necessary servicing of the bearings. More reliable lubrication and better bearings have resulted in less frequent interruption from bearing failures, more reliable operation, and saving in power.



Method of maintaining tension on silent chain drives with fixed centers.

The Link-Belt automatic idler and back-chain, which have been used on automotive front-end drives, have been applied to machine tools to maintain tension and take up for wear. This automatic take-up is used on the upper vertical chain on this machine.

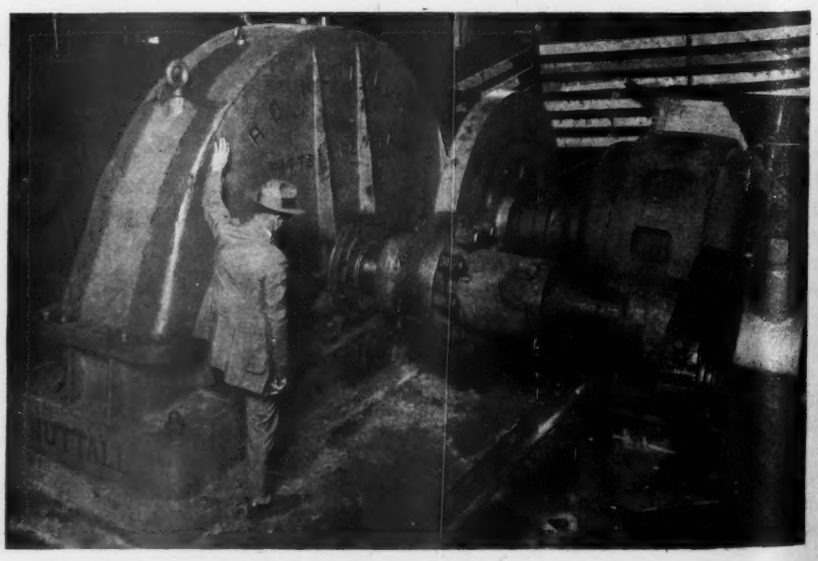
Some of the more outstanding examples of different types of equipment to which these bearings have been applied may merit a more detailed description, if for no other reason than to show how the difficulties in connection with their application have been overcome.

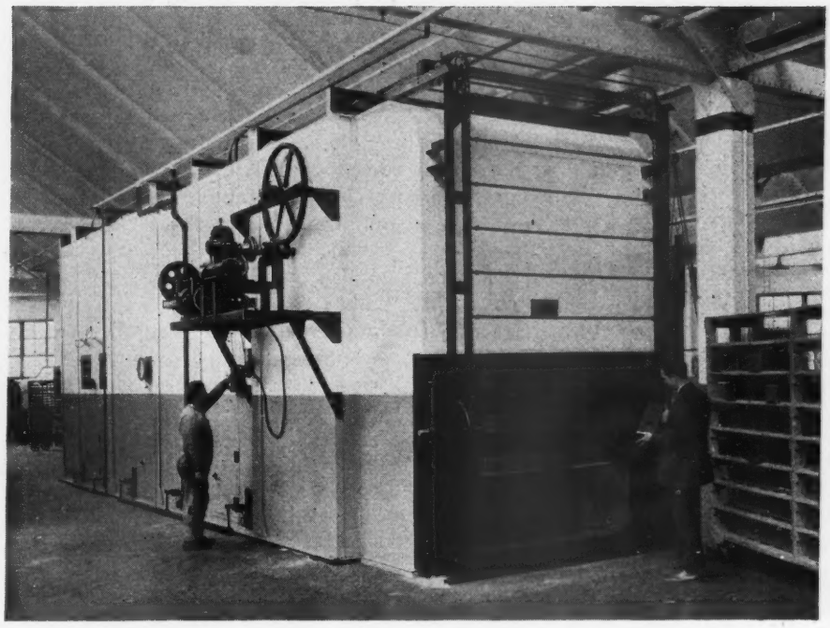
A typical example is the 350-hp., single-helical speed reducer shown in the accompanying illustration, which was built by R. D. Nuttall Company, Pittsburgh, Pa., and recently placed in service. In this installation, the pinion shaft has a four-bearing mounting; that is, there are two bearings, mounted back to back at each end of the shaft. Those at one end are given a press fit on the shaft, and arranged to hold the pinion in rigid alignment with respect to the main gear. The bearings on the other end are mounted so as to allow the shaft to float through them, partly to take care of shaft expansion, and partly to allow the pinion to locate itself with respect to the gear. The bearing mounting of the gear itself consists of a single bearing on each end of the shaft, the cone being a press fit on the shaft, and the cups permanently located by the housing. Timken tapered roller bearings are used throughout. Expansion and thrust have been two of the difficult problems involved in the use of anti-friction bearings on such machine.

Babbitted bearings are still used in many plants. For their replacement or renewal considerable care must be exercised in melting the babbitt, particularly where special alloys are used, because a temperature that is too high or too low does not give the proper results. For this reason many plants are using electric melting pots with temperature indicators or con-

Single helical gear reduction on steel-mill drive.

This 350-hp., R. D. Nuttall unit is equipped with Timken tapered roller bearings on pinion and gear shafts. The method of mounting the bearings to provide for thrust and expansion of the shaft is explained in the text.





Push-button controlled variable-speed drive on an oven.

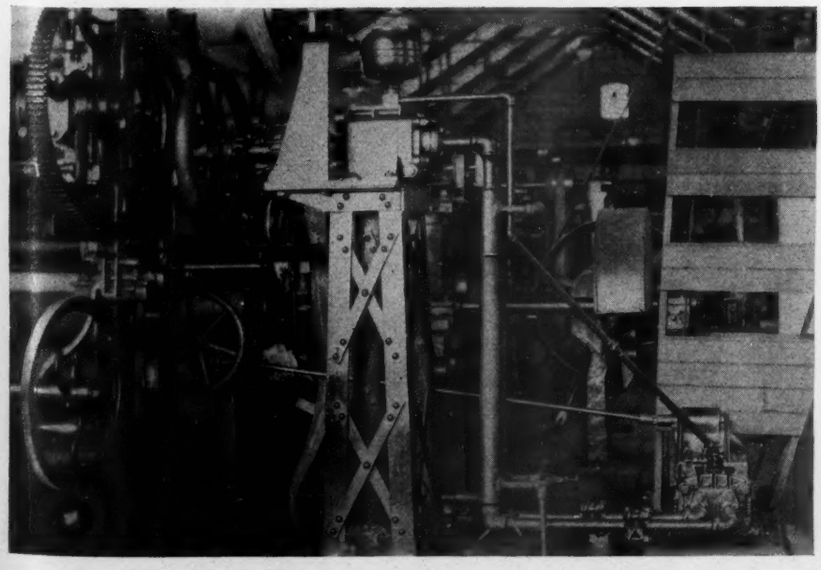
This continuous oven is used for baking the finish on Atwater Kent radio cabinets. Variable speed is obtained through a Reeves transmission by push-button control.

trol for melting the babbitt or other bearing alloys.

Belts—Operating men quite generally report an increased use of cemented endless belts on main drives, particularly on belts 6 in. and wider and in some cases belts above 4 in. in width. In some plants endless belts are used only where there is provision for take-up. It is interesting to note that improvements have been made in both the Clipper and the Detroit belt lacing machines. Each has brought out a lacer of increased size for the metallic lacing of belts.

An interesting new type of belt that is being tried out on hard drives in a wide variety of industries consists of a combination of leather and fabric with plies of each cemented together. This belt is sold under the trade name of Tex-Tan and is manufactured by Wayne Belting and Supply Co., Fort Wayne, Ind. Belts of this construction are claimed to have the advantages of both fabric and leather belts.

There has been a very much increased application of short-center or flexible-gravity idlers to belt drives. Although these were originally used on difficult drives or to compensate for extremely small pulley diameters, they have now come to be considered as a regular part of a belt installation, particularly where the driving pulley is small. The use of gravity idlers has overcome many of the operating problems connected with such drives because the idler gives much greater contact on the small pulley and at the same time decreases the necessary tension in the belt and the pressure on the bearings. These idlers are still almost a necessity on difficult belt drives, because, if properly applied, they get all possible driving capacity out of the belt. Recently some of these idlers have been used on quarter-turn belts.



Variable-speed drives are widely used on paper machines.

This illustration shows a Universal Hydraulic Variable Speed Gear driving a paper cutter. The pump or A-end of the gear is mounted on the floor and driven by a belt from the variable-speed line of the paper machine. Oil is piped from it to the B-end which is mounted on the pedestal and connected to the cutter shaft. The speed of the B-end is controlled by the hand-wheel shown just in front of the lower size press roll. Use of this drive has made it possible to reduce the amount of stock left for trimming from about $\frac{3}{8}$ in. to $\frac{1}{8}$ in. per cut.

The Texrope drive, which consists of several special-type V-belts running in grooved pulleys, is being used in a number of installations of 100 hp. rating and over. The article beginning on page 484 of this issue contains a number of interesting applications of this drive in a cement plant where it is subjected to severe service, due to abrasive dust in the atmosphere, heat and shock loads.

Chains—Users of chain drives are realizing that more careful consideration must be given to the service conditions when laying out such drives. Underrating, the failure to take into consideration severe operating conditions, and misalignment, are probably responsible for the larger proportion of operating difficulties that have occurred in connection with various chain drives.

The increasing use of silent chain drives on machine tools when center distances are fixed has led to the use of an automatic idler and vibration damper, similar to that used on automobiles, because some provision must be made for taking up any wear or slack and maintaining tension on the chain. A special idler sprocket for maintaining this tension has been announced by the Link-Belt Company. An application of this device is shown in one of the illustrations.

Flexible Couplings—There appears to be a decrease in the former practice of many plants of making their own flexible coupling from a pair of flange couplings by placing staggered pins on the faces and interweaving a short, endless piece of belt on the pins. This home-made coupling works fairly well on slow speeds and light loads,

but it is not balanced unless by accident. Much better service can be obtained by selecting a suitable flexible coupling from the variety of types available from manufacturers and dealers. More standardization in shaft sizes would permit stocking and quicker delivery of couplings from these sources.

In the newer designs of couplings it is common practice to make the coupling able to withstand any load that may be applied to a shaft which will fit the maximum permissible bore of the hubs. This practice, it is claimed, makes the coupling as strong as the shaft, and so it cannot be overloaded.

Several types of lubricated flexible couplings have been brought out and, in addition, practically all manufacturers of couplings have improved their designs within the past few years to simplify the construction, to strengthen the unit, and increase reliability. There has been an increasing tendency towards the direct application of a motor, gear, or speed reducer to a shaft by direct connection through a flexible coupling. On speed reducers, for example, couplings are usd on both high- and low-speed shafts (when direct connected to the shaft) instead of only on the high-speed shaft, as was common practice when the function of the flexible coupling was not so well appreciated.

Clutches—Although a few manufacturers have improved or redesigned their clutches to meet modern high-speed, heavy-duty applications there is still considerable opportunity for improvement by designing less complicated and more rugged units. Because of the difficulty of obtaining clutches suitable for modern power transmission requirements, many operators try to arrange equipment so as to eliminate the necessity of using a clutch. For example, hydraulic variable-speed transmissions which can be used to obtain any speed from zero to full input speed have been installed to obtain not only the variation in speed desired but also to take the place of a clutch and throw the machine out (zero speed) and pick up the load gradually.

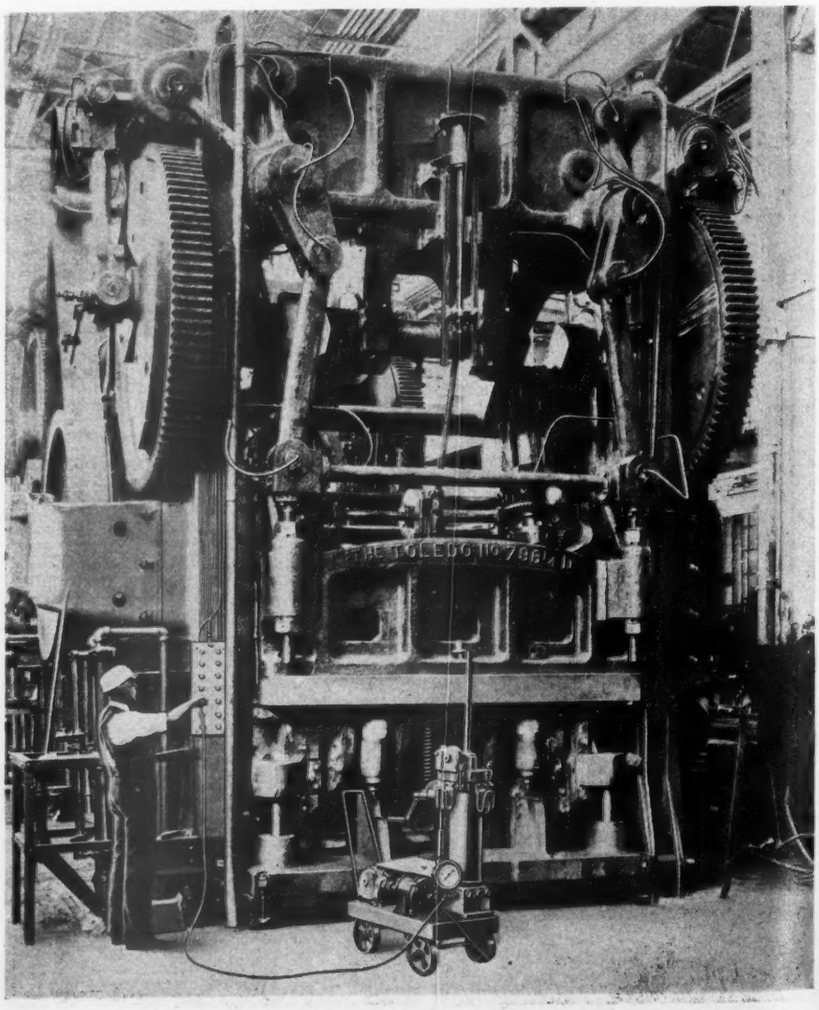
Gears—Items of particular interest concerning the application of gears are the wider use of non-metallic gears and the increased use of heat-treated, tool-steel pinions on drives subject to abrasive atmospheres or excessive wear.

Gear users have not fully appreciated the advantages or purpose of using non-metallic gears on noisy or hard drives. Often these gears have been put on without removing the cause of the noise, or improving service conditions. In some cases, these gears improved conditions but wore rapidly. Usually, when the cause was traced down wear was found to be due to misalignment. Users are beginning to pay closer attention to alignment and to obtaining perfect tooth fit and clearance.

The work of the American Gear Manufacturers' Association in the improvement of gear design, manufacture, and suggestions on operation has been mentioned previously.

Speed Reducers—It is interesting to note the extensive redesigning that has taken place in the past few years in speed reducers, particularly those of the worm type. Practically every manufacturer of worm-gear speed-reduction units has brought out new and improved models within the past year or two, or added vertical units to his line. In most cases the improvements have included a much larger case to hold a greater quantity of oil and also to provide larger radiating surface to cool the oil, special alloys for both worm and gear, which in some cases are heat-treated and ground, and ball, roller, or special bearings. In some designs pumps or other facilities have been provided for lubricating the worm when it is placed above the gear. There is an increasing tendency to use an outboard bearing where a pulley or sprocket is mounted on the slow-speed shaft.

Some progress has been made in the introduction of standardized worm and other reduction gear units in certain standard reductions and the carrying of these in stock by some of the companies or their distributors. This includes some small double-reduction worms for high reductions of 100 to 1 and larger, in rating of 1 hp. and under. Link-Belt Company



New type of centralized control for lubrication of large machinery.
Individual pipe lines from the bearings terminate at a central station. The lubricant is forced under high pressure to the bearing by Dot hand guns or portable power-driven compressors. This machine has a production value of $30 per hour. It formerly required about an hour for two men to climb over the machine and fill and screw down the 56 grease cups. Now it is not necessary to stop the machine for lubrication.

has brought out the Caldwell speed reducer which consists of a fixed reduction ratio gear unit to be direct-connected to the load and standard chains and sprockets which are carried in stock in various branch warehouses are used to connect the motor to the reducer and thus obtain any of a number of standard reductions. These units are especially designed for use on elevators and screw conveyors. The Cincinnati Tool Steel Gear & Pinion Co. has brought out a mill-type speed reducer with heat-treated gears, especially adapted for hard service in steel mills, cement plants, and other similar industries. In addition, there have been extensive development and redesigning of several makes of mill-type and herringbone speed reducers.

It is reported that paper mills are using a number of speed reducers on various drives to give a more direct reduction and closer connection. Also, in many lines of work a speed reducer is now connected directly to a lineshaft through a flexible coupling, thus simplifying the drive, by eliminating a gear or chain connection.

Variable Speed Transmissions— Although variable speed drives are not new, industry still has many opportunities for adopting them. Almost any machine that is used on a variety of work has a best operating speed for each type of work. It is difficult to obtain this variation in speed except through the use of an electrical, mechanical, or hydraulic variable-speed device. The manufacturers of mechanical and hydraulic variable-speed transmission units have made considerable improvement in design recently to improve operation. The Reeves unit, for example, can now be provided with a motor-driven speed control that can be operated to increase or decrease the speed from push buttons. The speed-control motor is independent of the start or stop control of the motor driving the variable-speed transmission. Improvements have also been made in the Reeves belt. Both the Reeves and the Lewellen variable-speed transmissions may be obtained with anti-friction bearings.

Manufacturers of hydraulic transmissions have also made considerable development and improvement in their equipment and have applied them to a much wider field of industry. The Oilgear, for example, is used on numerous applications in the machine-tool and other special fields. Some of these applications are quite new and are being studied preparatory to future announcements of the operating results. Applications of the Universal Variable-Speed Gear, an hydraulic unit, have been made in units up to 200-hp. rating.

The JFS variable-speed transmission has been taken over to be distributed by Stephens-Adamson Manufacturing Co. This unit, which has been described in previous issues of INDUSTRIAL ENGINEER, is a mechanical device in which a special double-cone-shaped roller is shifted in a special race to give a variable speed. A planetary transmission may be built into the unit to give additional reduction.

Lubrication — Perhaps the most noticeable feature in connection with the solution of power transmission problems today is the greater attention that practically all industrial plants are giving to lubrication. Bearing performance is practically dependent on proper lubrication and continuous operation is dependent to a very large degree on bearing performance. The improvements in the methods of application of lubricants has advanced directly along with improvements in bearings. Each has helped to make the other possible.

Unless lubrication is handled properly a considerable percentage of the lubricant is wasted. Many industrial plants are finding that they can cooperate to advantage with the lubrication engineers of some of the oil companies specializing in this work in a study of the plant lubrication problem. Although much of the interest of users is aroused through the possibilities of making savings in the cost of lubricants, the savings resulting from decreased maintenance and continuous operation are usually much greater, although they cannot be so easily evaluated.

Considerable attention has been given within the past year or two to the use of automatic and force-feed lubrication. This includes the Alemite, Dot, and Zerk systems, some types of automatic-feed grease cups, and numerous other force-feed lubricating systems.

Two of the recently announced improvements are the Dot-O-Matic pressure grease cup and the application of centralized Dot lubrication, either from a hand gun or a power-driven gun, as is shown in the accompanying illustration on page 450. In this centralized system of lubrication small pipes extend from a central point which contains a battery of Dot fittings. The operator, while standing on the floor, can lubricate bearings on any part of the machine by applying the hand gun or the power gun to the fittings and forcing the lubricant through the pipes to the bearing.

On the press illustrated two men formerly spent about an hour each day climbing over the machine to lubricate the various bearings, some of which were almost inaccessible. During this time the machine necessarily remained idle. Since the installation of the new method of lubrication the operation of the machine is not interfered with and all bearings on the entire unit are lubricated in about 10 or 15 min. by one man. Each bearing receives individual attention.

The Dot-O-Matic automatic-feed grease cup resembles an improved compression grease cup provided with a Dot fitting for filling. The rate of discharge can be regulated to require from a day to a week. These cups are used on glass machines and other equipment that is in continuous operation and requires lubrication under severe service conditions.

The application of an Alemite fitting to a compression grease cup has been made by the Link-Belt Co. This development removes one of the most objectionable features of the grease cup in that it can now be filled without opening. Opening a grease cup to refill in dusty surroundings always exposes the lubricant.

These newer methods of application of grease to bearings are not in any respect similar to the old method of using grease. In the old-type, grease-lubricated bearing a heavy grease was generally used. In some cases the increased temperature of the bearing was depended on to melt the grease and distribute it. A grease of much lighter consistency is used in the automatic grease-feeding devices, in pressure guns, and other force-feed lubrication systems.

There has been considerable advancement recently in the use of oil circulating systems in connection with paper mill lubrication. This application is not entirely new but has passed through the development stage and now is becoming quite widely used. The oil passes through filtering and cooling equipment after leaving the bearings and is recirculated. Oil used in large gear cases in steel mills equipment is also frequently recirculated. These bearings use large quantities of oil, and because of its value and the danger of contamination if not properly cared for, greater attention is being given to oil storage and handling facilities.

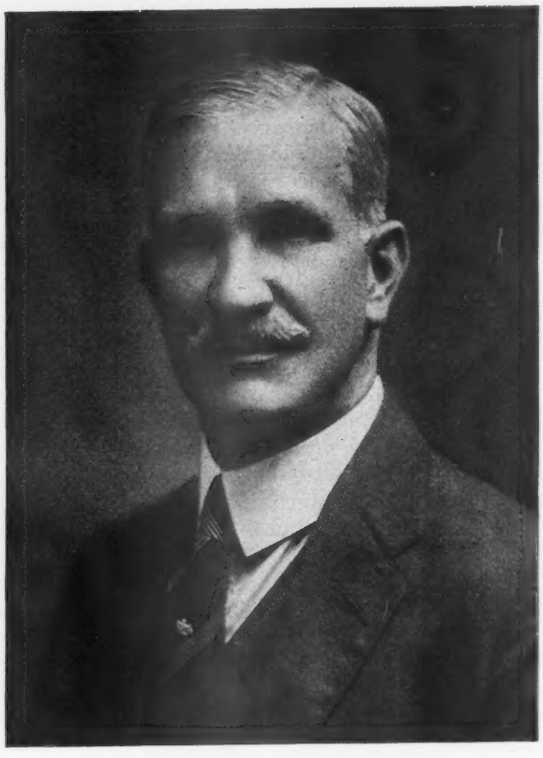
Every Power Drive Application Is an Individual Problem

By GEO. L. MARKLAND, JR.
Chairman of the Board, Philadelphia Gear Works, Philadelphia, Pa.

IN THE early days of our development as an industrial nation, power transmission problems did not play a very important part in plant operation. Industrial plants were comparatively few in number and small in size. Operating requirements and conditions were not very severe, as a rule, and efficiency of operation and reliability of service were not on the same plane they are today.

In these old plants one or more steam engines furnished all the motive power, which was transmitted from engines to lineshafts and from lineshafts to the machines almost entirely by leather belts. For the most part belts were well adapted to the demands placed on them.

As industrial plants became larger and were equipped with more complicated machinery, the problem of getting power from the engine to the machines became more troublesome. Then, too, the electric motor appeared on the scene and brought with it other problems that demanded attention. Essentially a high-speed machine, as compared with steam engines, provision had to be made for obtaining greater reductions in speed when a motor was used. As a result, other methods of connecting the source of power to the machine were needed, so that gears and, later on, chains, began to find wide application.



GEO. L. MARKLAND, JR.

As power transmission problems have become more complicated and the requirements more exacting, the manufacturers of power drive equipment have done a great deal of development and research work.

The tanning of leather is one of the oldest industries: yet within the past decade or so, many improvements have been made in the tanning and treatment of the leather used for making belts. A high-grade belt of today will render a quality of service that would have been impossible to obtain 25 or 30 years ago.

Twenty years ago gear drives were a nuisance, and regarded as a necessary evil. Usually they were extremely noisy in operation, and used valuable space.

Today the picture is entirely different. The metallurgist has given us special alloy steels and shown us how to heat-treat them to produce qualities and characteristics that were hardly dreamed of a few years ago. Old tooth-forms have been perfected, and new types of gearing developed. Radical changes have also been made in the methods and equipment used in cutting gears. These improvements have not only reduced unit costs, but have made it possible to cut gears to much closer limits than was formerly the case. The result is much quieter operation, reduction in the amount of power wasted through friction, and longer life of the drive elements.

Enclosing gear trains in an oil- and dust-tight case was a big step toward making gears serve more satisfactorily the needs of modern industry. Modern high-grade speed reducers are practically noiseless in operation, efficient, long-lived, require little attention, and present no injury hazard.

Chain drives have likewise been developed to a high state of perfection and are serving industry well. In fact, the same story could be told of every item of equipment that is used in the mechanical transmission of power.

As the result of all this development work, plant operating men today are faced with the problem of selecting the type of drive equipment that best meets the operating conditions and requirements in their plants. This is by no means always an easy task to accomplish satisfactorily.

There is no type of drive that is ideal for every application. All of the types of equipment that I have mentioned have won recognition because they have clearly demonstrated their value, when properly applied and taken care of intelligently. Each one possesses features that make it particularly adaptable to certain conditions.

In my estimation operating men cannot satisfactorily solve their power transmission problems on the basis of propaganda, hearsay, or personal opinion. These are essentially engineering problems and must be solved as such. This means that plant men must study their transmission problems individually with care, and make sure the requirements are not so severe that equipment will be called upon to do the impossible. Then, after thorough investigation of the methods and equipment available, they should select the type of drive that best meets all the conditions and will give the desired service with the greatest over-all economy and efficiency.

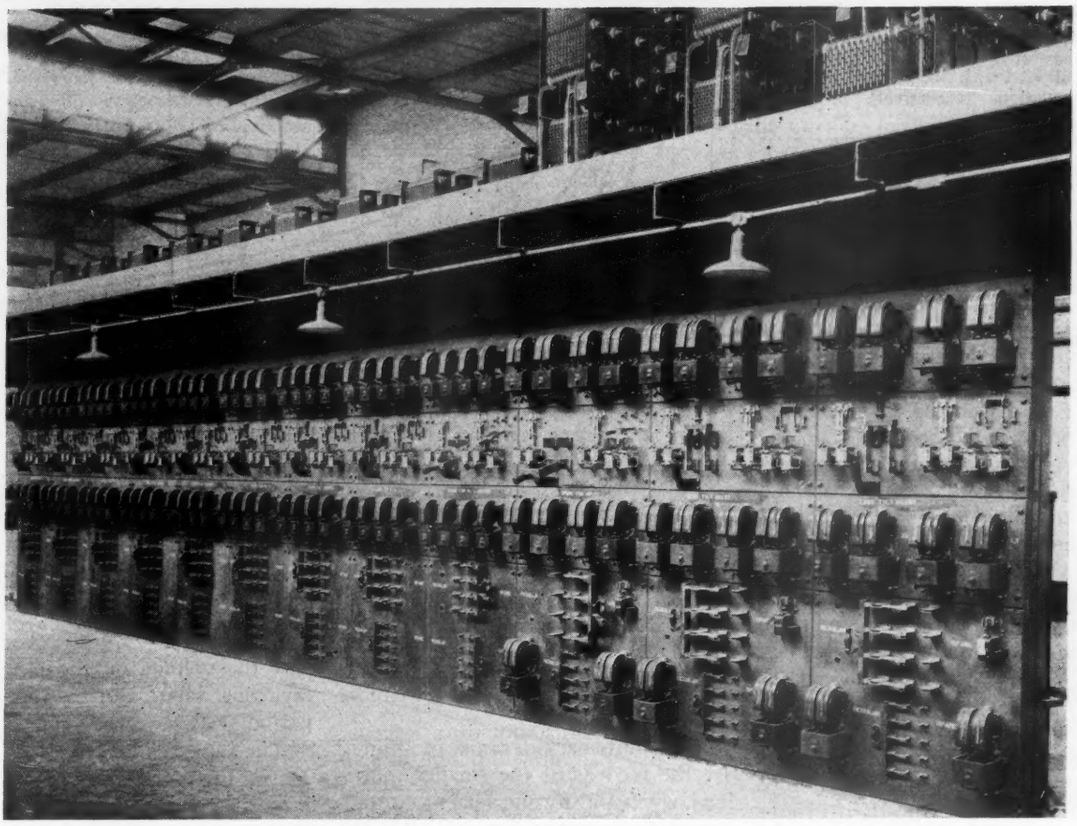


Fig. 1—These are the magnetic time control panels for the auxiliaries of a 28-in. structural finishing mill.

Time-Limit Control

of loads having large inertia

By B. W. JONES

Industrial Control Engineering Department, General Electric Co., Schenectady, N. Y.

IT IS quite generally recognized that time-limit control, like magnetic time direct-current control, gives good operating results when the motor drives loads like steel mill auxiliaries, crane hoists or similar loads where the inertia is not very great. Many questions, however, have been asked regarding the adaptability of time-limit control to loads which have a large inertia. This article will endeavor to analyze this subject and show what happens when the value of the inertia remains constant and the torque varies.

If both the inertia and the torque loads remain constant during the starting period, it is a simple matter to adjust each time relay so that the resultant current peaks will stay within the desired bounds. But, if the torque load varies the result is a little confusing. The relay setting given at the factory may not give the desired results and further adjustment on the job may become necessary. However, the factory setting can be made fairly close to the required value, and, therefore, the chances are good that little or no adjustment will have to be made in the field for the operating sequence.

The load condition that causes the most questioning is a fairly large inertia and also a widely-varying torque load. Let us assume that a series motor is driving the load and that the torque load will not materially exceed the full rated torque of the motor, but may range anywhere from rated torque down to zero. Also, assume that the time adjustments of the relays are such that the motor will accelerate the inertia load alone with one-half rated torque; that is, the relays provide sufficient time so that one-half rated torque of the motor will accelerate the inertia load. Now, if a half-rated torque load is added, the motor must develop rated torque during its accelerating period, in order to drive the inertia plus the half-torque load. Again, if a torque load equal to the rated torque of the motor is to be accelerated, the motor must develop one and one-half times rated torque in order to accelerate the inertia plus the torque load. From this simple analysis it is evident that any combination of inertia and torque loads can be handled without any complicated calculations.

The speed-torque curves of an MDS-106 motor are shown in Fig. 2 for a resistance having 30, 25, 20, and 15 per cent ohms in the several divisions. The left-hand group of steps shows the results when the

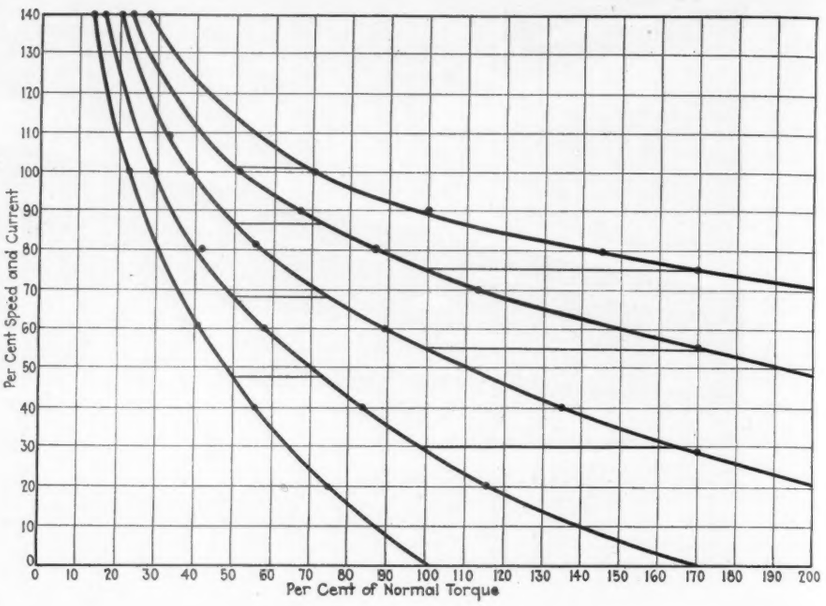


Fig. 2—Speed-torque curves of a series motor operated under different conditions of load with 30, 25, 20 and 15 per cent ohms respectively in the resistors.

The steps at the left represent the conditions when the inertia alone is accelerated. The right-hand group of steps shows the conditions when the inertia plus one-half rated torque is accelerated.

inertia alone is accelerated. The right-hand group of steps shows the results when the inertia plus one-half rated torque is accelerated. These steps are drawn on the basis that the several resistor divisions will be consecutively short-circuited when the current reduces to a 50 per cent value for the first or left-hand group of steps, and to 100 per cent value for the right-hand group.

However, the actual current value for the right-hand group will be somewhat less than these assumed values, which means that the maximum current peaks as shown in Fig. 2, are a little higher than they would be in practice. This is true because the resultant torque jumps between the left and the right groups of steps are more than 50 per cent, which are intended to take care of the 50 per cent added torque loads, and because the maximum speed at the higher load is lower than at the light loads.

A test was recently run to check the accuracy of the above assumptions. Oscillograph records were made of the current, the counter-e.m.f., and the time. For this purpose a series motor was geared to two inertia loads, one being 1.3 times the WR^2 of the armature, and the other one 20 times the WR^2 of the armature. The first case represents a very common value of inertia found in most loads, whereas the second case represents a very large amount of inertia, which is found in only a few loads. The torque loads were obtained by a friction brake. This was adjusted to represent various loads from practically zero to more than twice normal.

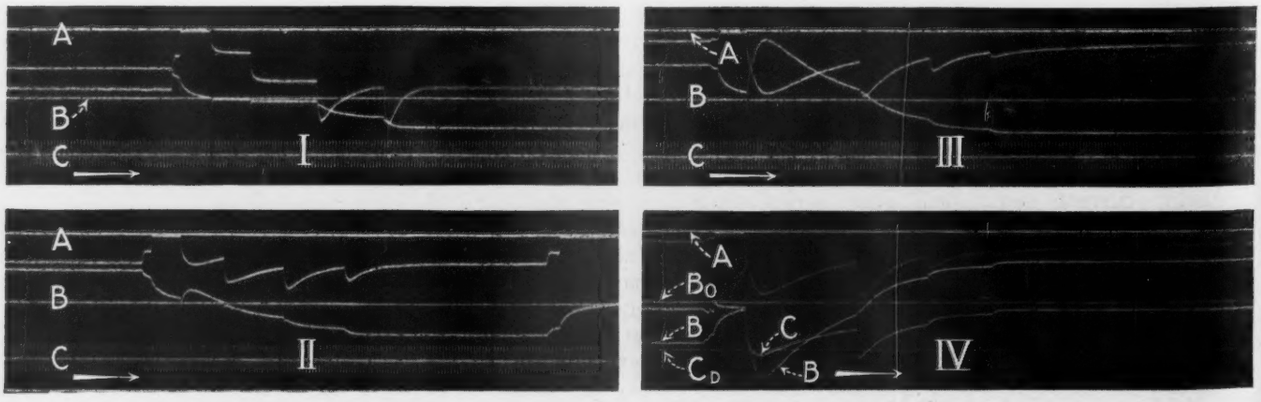
The four oscillograms in Fig. 3 are the records of the smaller inertia load when the torque loads were adjusted respectively for 200, 100, 33, and 33 per cent of normal. In these oscillograms curve *A* represents the armature current, and curve *B* the armature voltage. In Figs. 3, I, II, and III, curve *C* is the 40-cycle timing wave. In Fig. 3 IV, curve *C* shows how the voltage on the plugging relay coils varies during the plugging period.

The four oscillograms I, II, III and IV in Fig. 4 are the records of the larger inertia loads where the torque loads were adjusted respectively for 33, 100, 200, and 33 per cent of normal. The oscillograms in Figs. 4 I, II, and III have a 40-cycle timing wave; in Fig. 4 IV the timing wave is replaced by a voltage curve, which shows how the voltage on the plugging relay coil varies during the plugging period. In these oscillograms also, curve *A* represents the armature current, and curve *B* the armature voltage. The result of an analysis of these oscillograms, in Figs. 3 and 4, showing the currents, volts, and time in seconds between closing of contactors is given in the accompanying table.

It will be seen that the voltages impressed on the coil of the plug relay at the instant when the line contactor closes (when the motor is plugged) and when the plug relay

Fig. 3—These oscillograms show the conditions when operating a series motor under a small inertia load and various values of torque load.

The inertia load was 1.3 times the WR^2 of the armature. Oscillogram *I* represents a reversing test with a torque load of 200 per cent of normal; *II*, with a load 100 per cent of normal; *III*, with a load 33 per cent of normal; *IV*, an acceleration test with a load 33 per cent of normal. In these oscillograms curve *A* represents the zero line of the armature current and *II* the armature voltage. In oscillogram *IV* the 40-cycle timing wave has been replaced with a voltage curve which shows the voltage variation across the plugging relay coils during the plugging period. These oscillograms, as well as those in Fig. 4, are analyzed in the table given in the text.



Analysis of Oscillograph Records Shown in Figs. 3 and 4

Time in seconds between closing of contactors

Torque Load Per Cent	Light Inertia Load			Heavy Inertia Load		
	Line and Plug Contactors	Plug and 1A Contactors	1A and 2A Contactors	Line and Plug Contactors	Plug and 1A Contactors	1A and 2A Contactors
33	.87	.52	.48	5.3	1.88	....
100	.37	.52	.48	2.65	1.87	1.5
200	.30	.52	.52	1.4	2.00	1.55

Current values just before and after closing of contactors

Torque Load Per Cent	Light Inertia Load				Heavy Inertia Load			
	Line Contactor	Plug Contactor	1A Contactor	2A Contactor	Line Contactor	Plug Contactor	1A Contactor	2A Contactor
33	0/340	170/350	148/222	117/138	0/258	140/320	206/350	.....
100	0/160	127/255	180/286	170/244	0/216	144/310	227/410	250/420
200	0/122	122/265	265/470	308/490	0/185	135/290	260/485	340/620

picks up to let the plug contactor close, are:

Minus 24 volts when the line contactor closes.

Plus 133 volts when the plug relay closes.

It is evident from these results that time control is applicable to light and heavy inertia loads where the torque loads vary over wide limits.

Fig. 5 represents the graphic ammeter record of the current input to a 70-hp., 220-volt series motor with magnetic time control. This motor drives a rail-mill table approximately 75 ft. long, consisting of 20 rollers. Extremely rapid operation is not essential to maintain the desired production and the timing of the relays has been adjusted to give a rather long delay. The interval between the closing of the forward or reverse contactors and the closing of the last accelerating contactor is approximately 1.8 sec. when the motor is started from rest. When the motor is plugged the interval is about 3.75 sec.

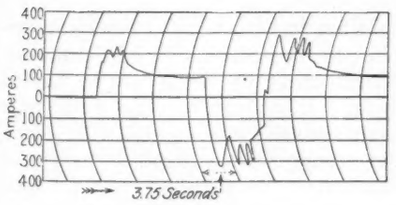
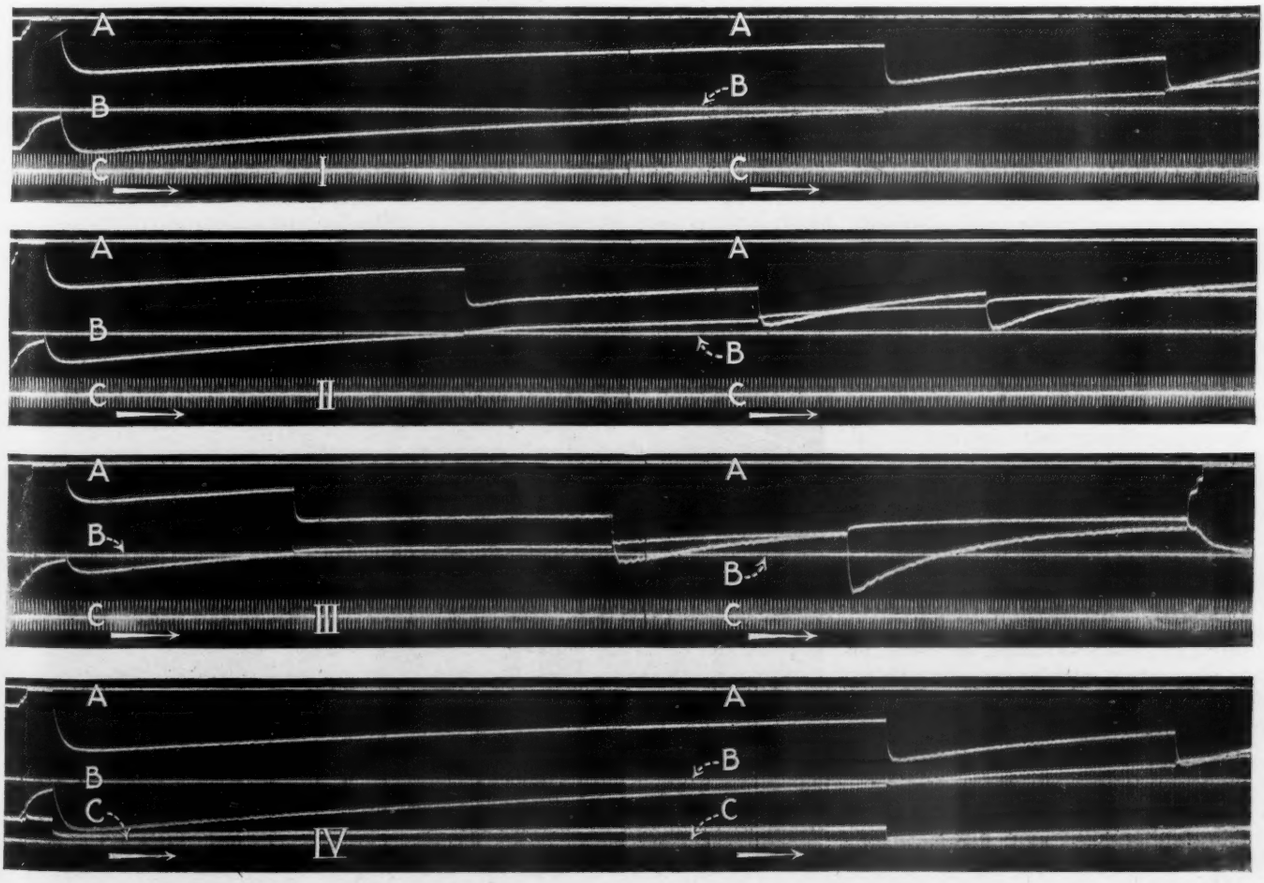


Fig. 5—This graphic ammeter record shows the current drawn by a 70-hp. reversing series mill motor controlled by a magnetic time controller.

With the type of control previously used with this motor the current peaks were between 700 and 800 amp. Since the installation of the present controller the current peaks have been reduced to a maximum of about 350 amp., as will be seen from Fig. 5.

Fig. 4—In this case the motor was reversed under a heavy inertia load and different values of torque load.

The inertia load was 20 times the WR^2 of the armature. Oscillogram *I* shows the conditions when the motor was reversed under a torque load 33 per cent of normal; *II*, under a load 100 per cent of normal; *III*, under a load 200 per cent of normal, and *IV*, under the same load with the 40-cycle timing wave replaced by a voltage curve showing the voltage across the plugging relay coils during plugging. As in the case of Fig. 3, curve *A* in the oscillograms represents the zero line of the armature current and curve *B* the armature voltage.



What has been said heretofore applies to the acceleration of the motor. Inasmuch as the motor may be started from rest, or may be plugged from a high speed in the opposite direction, the plugging contactor should be controlled by some current-limiting means. In the General Electric magnetic time type of control, the principle of having the counter-e.m.f. of the motor buck the IR drops of the plugging section of the resistor, is used. This causes the plugging contactor to close instantly if the motor is at rest, but if the motor is running in the opposite direction, it must come substantially to rest before the plugging or any of the accelerating contactors can close.

It may, therefore, be assumed that control working on the function of time can be applied to loads that have a widely-varying torque value such as a crane hoist, or to an inertia load such as the trolley motion on a man trolley ore bridge, or to an inertia load which has, in addition, a varying torque load, such as a low-pressure fan which may have the discharge either open or closed. It should not, however, be applied to a load whose inertia is of large magnitude as compared with its torque load, and varies to a considerable degree. Such a load is, however, very uncommon.

The principal limitation in applying time-functioned control for direct-current motors has not been its misapplication to the varied types of loads, but has been the lack of a suitable relay for producing a sufficient time delay for some loads. An impetus towards the use of time-delay control has been given by the design of the magnetic time control mentioned, which uses an induction time-delay relay. The controlling relays on these panels are simple, and dependable, which are the requirements for success. However, they have one limitation: the maximum time for which they can be adjusted is approximately 1 sec., and there are some applications where more than 1 sec. per relay is required.

Recently, a new relay has been developed that can be mechanically connected to direct-current contactors rated at 150 to 600 amp., inclusive, or to alternating-current contactors rated at 75 amp. and above. It can be adjusted over a range of 0.5 to 8 sec. Therefore, by means of the induction time-delay relay for direct-current control and the new relay for either alternating- or direct-current control, the principle of time delay for governing the acceleration of motors can be used for the majority of control applications.

Using Two Idlers to Increase Arc of Contact

IN A large plant that was rapidly expanding, it was found necessary to increase the load on the engine from about 170 hp. to 275 hp. Space limitations prevented a change in the respective positions of the driving and driven pulleys unless very expensive alterations were made. Consequently, it was decided to devise some method of increasing the horsepower transmitted, without making any radical changes in the layout.

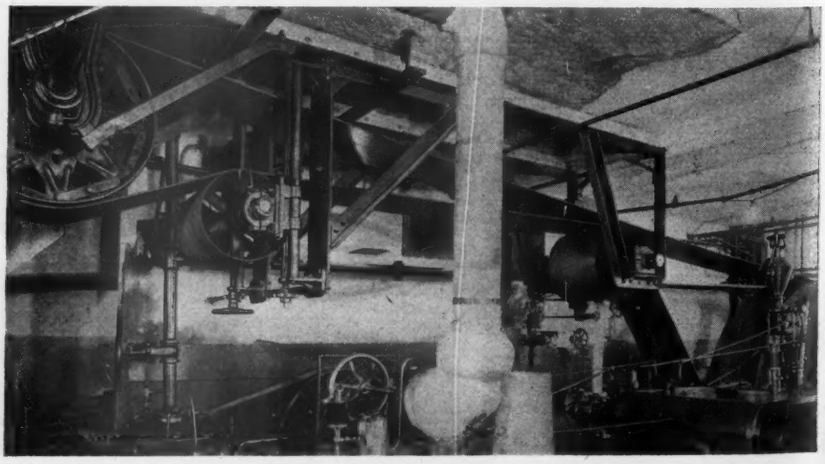
Triple-ply leather belts 20 in. wide had previously been used on this drive with unsatisfactory results, when the load was increased. These belts had stood up only from four to nine months, running at a speed of a little more than 2,600 f.p.m.

The pulleys are of fair size and in order to increase the arc of contact on the pulleys and also raise the lower strand of the belt over some other equipment that was in the way, two idler or carrier pulleys were installed. One of these idlers is adjustable so that the belt tension can be regulated.

In view of the severity of the service to which the belt was subjected a 20-in. Gripotan belt with a Tannate ply on the side next to the pulleys was installed. This belt has now been in use for more than five years, carrying the maximum load of 275 hp. without apparent difficulty or need of much maintenance attention.

J. EDGAR RHOADS.
J. E. Rhoads & Sons,
Philadelphia, Pa.

Use of a special belt and two idlers made it possible to increase considerably the load on this drive.



Abuse of Belt Drives on High-Inertia Loads

WHERE belts are used to transmit power from a motor to the driven machine it frequently happens that the most severe strain on the belt occurs when the motor is started. This is particularly true when the driven equipment has high inertia.

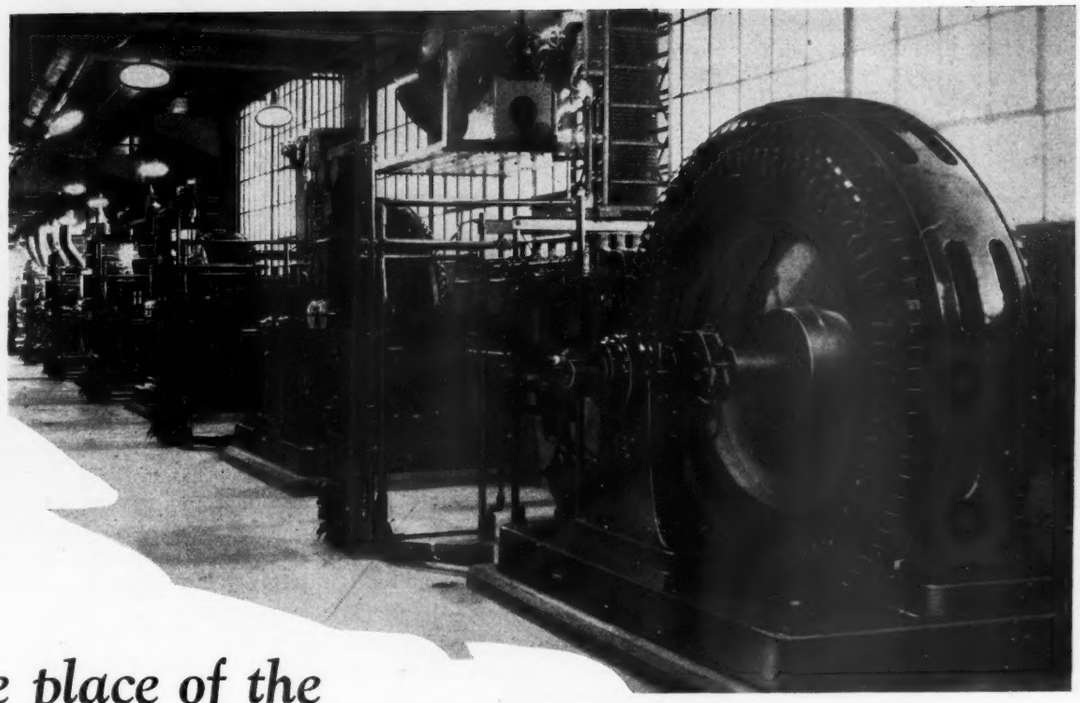
Present practice is to drive flywheel loads with a motor whose rating corresponds as closely as possible to the actual load. This necessitates the use of a high-resistance rotor, in order to obtain the required starting torque. If such a motor is started on too high voltage the torque produced may cause severe slipping and straining of the belt.

An instance of this sort came up in a large eastern plant. Here the motors driving the heavy abrasive wheels on a number of swinging grinders were being started on such high voltage that they came up to speed too rapidly. In consequence the belts were short-lived and gave a great deal of trouble.

The frictional heat generated by the belts slipping on the pulleys would char the inside of the belt in spots. There was also a tendency for the belts to narrow down and the surface developed deep cracks, clearly showing the strain to which they had been subjected.

The obvious remedy was to start the motors on a lower voltage than could be obtained with the starting equipment than in use. Accordingly, our primary-resistance starters were installed. These starters make it possible for the operators to bring the motors gradually up to speed, so that the grinding wheels have more time to accelerate and belt troubles have been eliminated.

W. B. NEEPER.
Engineering Dept.,
Allen-Bradley Co.,
Milwaukee, Wis.



1,000-hp., low-speed synchronous motors driving pulp grinders.

The place of the Synchronous Motor *in industry*

By C. D. KESTER

Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

ADVANTAGES resulting from the use of synchronous motors have not until recent years been fully appreciated. Before the war the price of generating and other power plant equipment was such that little attention was given to power factor and the means by which it could be improved.

During this period the principal synchronous motor applications were on the low-speed compressors, the larger centrifugal pumping installations and, of course, motor-generator sets. Inasmuch as the compressors operate at low speed, the synchronous motor represented a lower first cost than induction motors and provided better performance. The pumping installation represented in most cases a steady, continuous load, where higher cost for high-speed synchronous motors could be justified by their higher efficiency.

Large motor-generator sets were usually operated continuously, and in a number of cases power factor correction was supplied by applying the proper synchronous motor. Here again high efficiency was important, even if no power factor correction were desired.

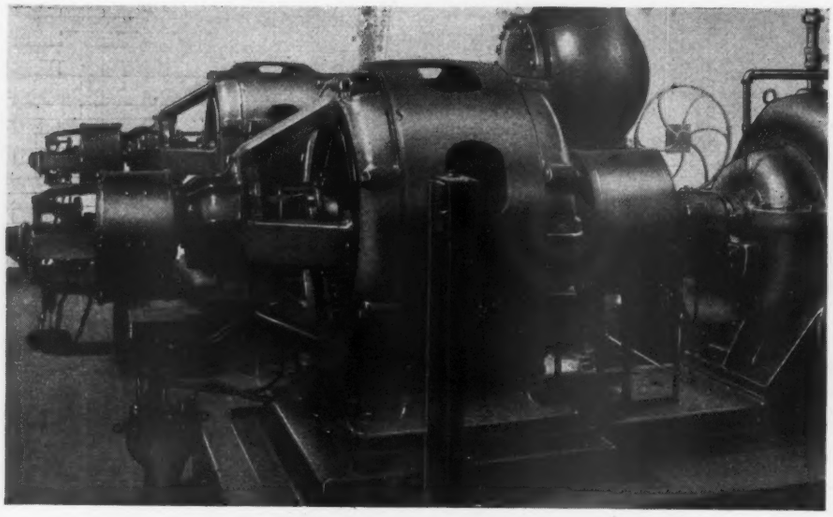
As late as 1919 the total demand for synchronous motors was only a small percentage of the present-day demand, and until that time had been too small to induce manufacturers generally to design synchronous motors with the most advantageous characteristics. The existent demand was in general supplied by motors made from existing alternating-current generator parts. This often necessitated sacrificing some important motor characteristics. Also, in former days the starting equipment was somewhat cumbersome and required fairly skilled operators.

As soon as we settled down to real business after the war, something happened. The price of power plant equipment had soared so high that the derating effect of low power factor on generating equipment was studied in earnest. Large power companies found that raising the power factor of their load from 65 per cent to 85 per cent was equivalent to installing an additional 20,000-kva. turbo-generator.

Following up this situation logically and patiently on the part of central stations and other large power producers gave synchronous motor demand an immense impetus. As the demand grew, motor manufacturers gave more and more attention to the design of synchronous motors and starting equipment for them.

The user of synchronous motors was already enjoying lower power bills due to better performance of these machines, but now he began to benefit by the better power rate based on his high power factor. This growing appreciation of benefits of high power factor, together with the development of simple and dependable starting equipment, has brought about the rapidly increasing demand for synchronous motors.

The power factor of every plant using alternating-current equipment should be given careful consideration. The lagging power factor caused by induction apparatus such as transformers, induction motors, electric



High-speed synchronous motors are well adapted for driving centrifugal pumps.
The two motors shown here are of 300-hp. rating and have direct-connected exciters.

furnaces, and so on, is brought about by the magnetizing current drawn from the line. Low power factor means larger generating, transmission and transforming equipment in order to provide the necessary useful or load current. The voltage regulation is also likely to be poor.

The purchaser of power is penalized by low power factor in his plant by the increased size of cables, switching, and other equipment, to say nothing of the voltage regulation, which affects the speed of loaded induction motors.

Whereas the magnetizing current is supplied to induction equipment from the power line, the synchronous motor supplies its own magnetizing current through direct-current excitation and is, therefore, capable of operating at a predetermined power factor—unity or some per cent leading for corrective purposes—depending upon the amount of excitation. Where suitable synchronous motor applications are available, power factor correction by this method is practically always the most economical. With a drive to be electrified the additional cost of a synchronous motor large enough to give power factor correction over the cost of one just large enough to carry the load is very small—practically always negligible when the benefits of high power factor are capitalized. Power factor correction has spread to such a point that there are now available high-speed, general-purpose synchronous motors in ratings of 200 hp. and down to 50 hp. and below for various applications. The high-speed motors above 200 hp. rating are known as large synchronous motors.

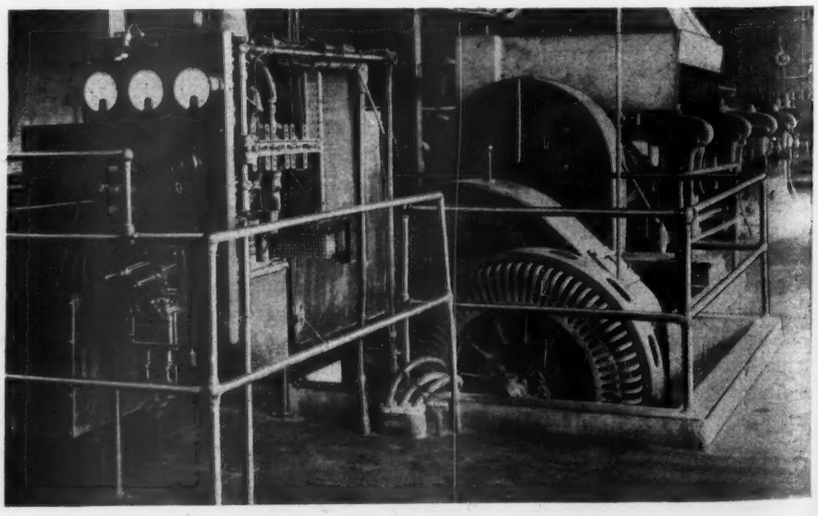
The modern synchronous motor is so designed that its electrical characteristics can be modified easily to meet the requirements of the majority of present-day industrial drives with the exception of those utilizing flywheel effect to advantage. Of course, flywheel effect is used in connection with synchronous motors driving compressors for smoothing out the impulses imposed by the compressor, but where the application uses a flywheel for carrying the peak loads, such as is experienced in certain types of steel rolling mills where there is a peak lasting for several seconds, the synchronous motor is not applicable. It is inherently a constant-speed machine. Hence we may say in general that synchronous motors are applicable to any constant-speed drive where flywheel effect, as heretofore explained, is of no advantage.

In simplicity of construction the synchronous motor is about on a par with a squirrel-cage induction motor, but it is simpler than the wound rotor motor; hence it can be said that it is at least as simple as if not simpler than induction motors as a whole and utilizes a larger air gap, which is a decided advantage. The synchronous motor requires additional equipment in the form of a source of excitation, either a separate exciter or excitation from a bus, but the exciter is a very simple and standard piece of equipment from which little or no trouble may be expected. Where one or more synchronous motors are installed in one location it is often feasible to excite them from a common bus, thus simplifying the excitation equipment.

In order to vary the excitation and thus the power factor at which the motor operates it is necessary to provide a rheostat. In most cases of individual exciter installations the small exciter rheostat only is required, whereas in some instances a main motor field rheostat is used. However, when starting up the majority of installations, the rheostat is set and forgotten. The simplicity and reliability of the rheostat are matters of common knowledge. The corrective effect of the synchronous motor increases as the load decreases, provided the normal excitation is allowed to remain constant.

These motors are built standard to operate at 100 per cent and 80 per cent leading power factor, and these two power factor classifications cover by far the majority of applications. The 100 per cent power factor machine is applied where very little corrective effect is necessary, or where it is desired to maintain practically the

This 350-hp. high-speed synchronous motor drives a rubber mill line through a speed reduction unit.

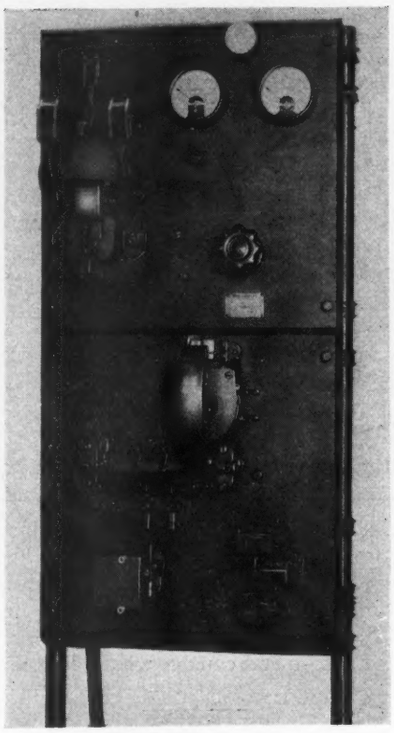


same power factor, whereas the 80 per cent leading power factor motor is used where corrective effect is required. Occasionally a motor of greater leading power factor, such as 70 per cent, is required and can, of course, be furnished on special order.

Synchronous motors are divided into two general classes according to speed: high speed, which includes those operating at 450 r.p.m. and above; and low speed motors operating at 400 r.p.m. and below. In appearance these motors differ essentially in width and rotor construction. The high-speed motors are comparatively wide, with laminated rotors and dovetailed poles, whereas the low-speed motors are comparatively narrow, having a rotor with bolted-on field poles.

High-speed motors are built in sizes below 50 hp., but it is difficult to justify the use of sizes very much below this because of the considerably higher prices, compared with those of induction motors and the relatively small amount of power factor correction possible. Above 50 hp. rating the inherent advantages of the synchronous motor must not be neglected. Also, the price difference between synchronous and induction motors is diminishing, as will be mentioned later.

Starting equipment for high-speed synchronous motors is very simple; the application of field excitation is done at the right time automatically. The starting operations are the same as for the squirrel-cage induction motor. Many high-speed motors below 1,800 r.p.m. can be thrown across the line without objectionable inrush of current, further simplifying the control. The current inrush is in general inversely proportional to the number of poles—the smaller the number of poles the higher the inrush on full-voltage starting.

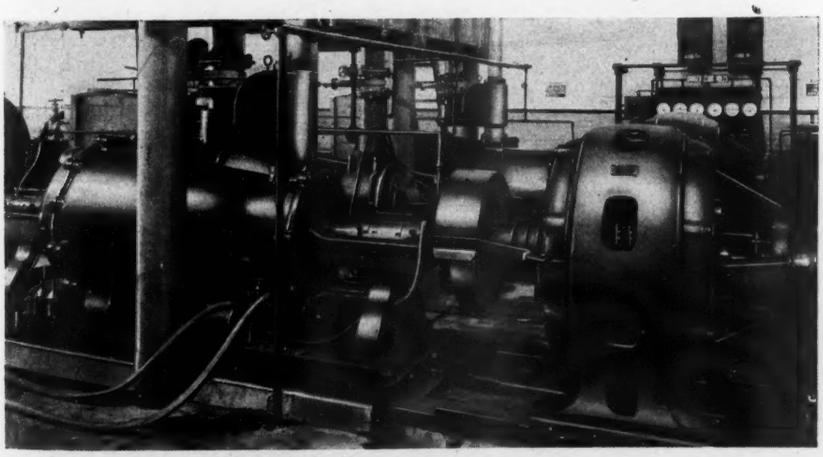


Control equipment for synchronous motors has been greatly simplified during the past few years.

This illustration shows a 2,200-volt fully automatic, across-the-line starter for a synchronous motor. All low-speed motors can be started on full voltage without objectionable current inrush. It is frequently desirable, however, to start high-speed motors on reduced voltage.

There is a sub-classification under high-speed motors to include high-efficiency centrifugal pump motors with ratings of 200 hp. and above at 1,200 r.p.m., and 100 hp. and above at 1,800 r.p.m. Most municipalities are insistent on high efficiency, and various industries are becoming more favorable to this class of motor for driving centrifugal pumps, especially those that are operating continuously under a reasonably steady load. The saving on such drives due to high efficiency is considerable. These motors cost quite a little more than the general-purpose and large, high-speed synchronous motors, but the high efficiency soon writes off this difference. For pumps requiring motors rated below the horsepower range heretofore given, general-purpose synchronous motors should be used down to, in general, 50 hp., and induction motors below this.

In this paper mill the jordans are driven by 400-hp., low-speed synchronous motors connected directly to the shaft.



High-speed synchronous motors are now extensively used for such applications as,

Belted to general lineshaft drives.
Belted to or coupled to centrifugal pumps.
Belted or coupled to fans and blowers.
Belted or geared through jackshafts to gyratory crushers.
Geared to reciprocating pumps.
Geared to rubber mill lines.
Geared to metal-rolling mills.
Belted to compressors.
Motor-generator sets.

Low-speed motors are also built in sizes below 50 hp., but the statements made in regard to high-speed motors apply, in general, here. Very good use can be made of a high-starting-torque, belted squirrel-cage motor for many cases where the demand comes much below 50 hp.

The starting equipment for low-speed synchronous motors is also very simple, with the field excitation automatically applied. All low-speed motors can be started on full voltage and the full-automatic, push-button-operated, across-the-line starting equipment is the most popular for these machines. Either hand- or magnetically-operated reduced voltage control can be used where desired if the starting torque on reduced voltage is sufficient for the particular application.

Low-speed synchronous motors are widely used as engine type for driving compressors and for such coupled applications as,

Sewage pumps.
Rubber mill lineshafts.
Pulp grinders and jordans.
Steel-rolling mills.
Band saw mills.
Ball, tube and rod mills.
Large slow-speed fans, blowers.

There are several high-torque applications for both high- and low-speed synchronous motors which require individual attention by the manufacturer of this type of equipment.

There is a second stage to the im-

petus behind this synchronous motor demand. The larger production than in former days results in economies that are reflected in the prices. In general the synchronous motor with direct-connected exciter costs only slightly more than the corresponding squirrel-cage induction motor in the smaller, high-speed sizes. This difference is greatest in the very small sizes and decreases as the size approaches 200 hp., rating, above which the price differential will usually be in favor of the synchronous motor. There are two exceptions to this—the high-speed pump motors previously mentioned, and the two-pole turbo type, which does not begin to compete with the squirrel-cage motor until a rating of 500 or 600 hp. is reached. The cost of the low-speed motor with belted exciter is pretty generally as favorable as that of either type of induction motor, and sometimes more favorable. Being built for speeds of 400 r.p.m. and down, the construction is simpler and less expensive.

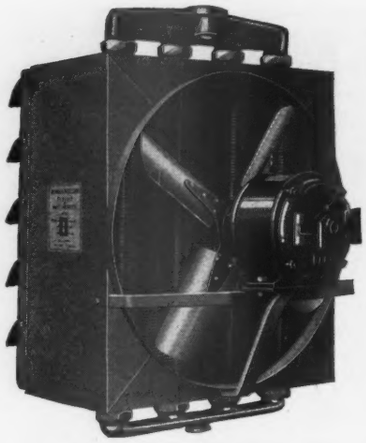
The ever-widening field of synchronous motor applications has brought about many improvements in design which are of direct benefit to the user. One of the latest designs is a low-speed, engine-type synchronous motor of welded structural steel construction. Directed ventilation is employed, giving even temperature rise with no hot spots.

The synchronous motor, together with simple and reliable control, is keeping pace with the demand and promises to eliminate much of the power factor waste that is still cutting into profits. It also promises to provide a more economical method of converting electrical into mechanical energy.

Correction in "Application of Unit Heaters in Industrial Plants"

DUE to a typographical error the photograph in the upper left-hand corner of page 353 of the August issue, in the article entitled "Application of Unit Heaters in Industrial Plants," was credited to another manufacturer when it should have been credited to The Herman Nelson Corporation, Moline, Ill. A later model of this Herman Nelson hiJet unit heater is shown here.

This unit heater is a special, extended surface, high-radiating capacity unit. The steam section or core of the radiator is wedge-shaped with aluminum fins extending at right angles. These fins are firmly wedged in parallel and keyed in position. The core is cast in one piece and, it is stated, that the wedging and keying of the fins on the core give a close, metal-to-metal contact which does not loosen.



Herman Nelson unit heater

Trouble with Calender Drive Traced to Eccentric Gear

IN a Chicago industrial plant, one of the hardest drives, at least from the standpoint of the amount of trouble caused, was on a calender roll.

The calender roll giving trouble was gear-driven from a motor whose pinion seldom averaged more than three months' service. Pinions of various materials were tried without much improvement or lessening of noise. It was evident that something was radically wrong with the installation, or the load was too great.

A careful check-up of the drive disclosed the fact that the large bull-gear had been bored slightly off center, but true. At slow speed the irregular motion was not obvious to the eye nor easily detected but a careful measurement indicated the high and low sides of the gear. This difference was greater than the clearance allowance and caused the teeth to bind during part of the rotation and operate with excess backlash when the other half of the gear went into mesh with the pinion.

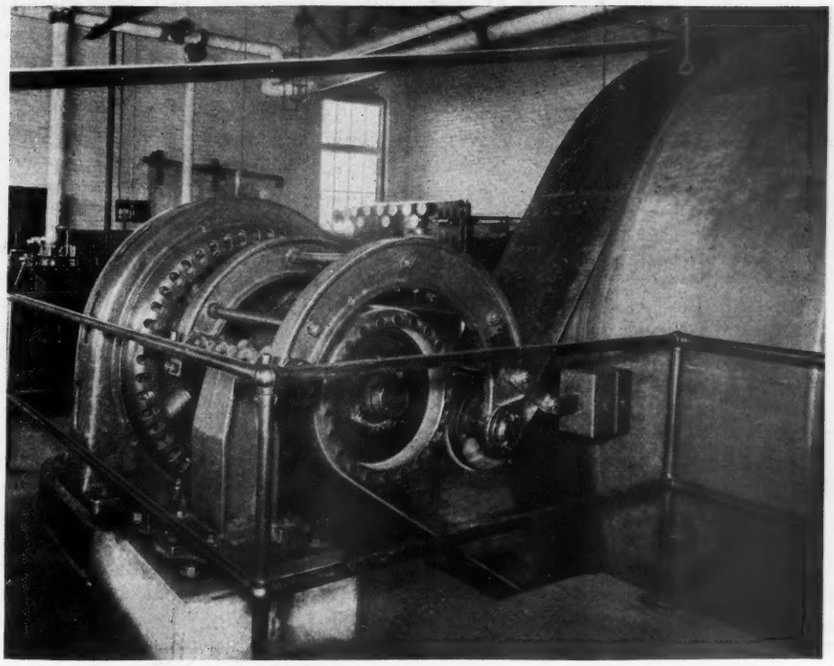
After locating the cause of the trouble, it was decided to change the drive entirely, instead of getting a new bull-gear. To give greater flexibility between the motor and the machine than is possible with a gear and pinion, but at the same time retain the positive feature of the gear drive, a chain drive was installed, similar to the calender drive shown in the accompanying illustration. The first drive was rated 45 hp. and an American High Speed chain was used.

This installation operated so satisfactorily that the drive illustrated was installed later on. This drive is of 100-hp. rating and connects the motor to a jackshaft built into and driving two calenders through gears. Only one of the calenders is shown in the illustration.

The jackshaft is driven at 55.8 r.p.m. from the 100-hp., 550-r.p.m. motor by a 12-in., 1½-in. pitch American High Speed chain running on 85.62-in. centers. A 19-tooth, case-hardened steel pinion is used on the motor and a 187-tooth, cast-iron sprocket on the shaft.

Chain drive on a jackshaft geared to two calenders.

The chain is used to absorb the shock and vibration and still maintain the advantages of a fixed ratio and positive reduction that would be given by a direct gear connection between the motor pinion and the large gear on this jackshaft. This chain sprocket is mounted on pillow-blocks and connected to the jackshaft by a flexible coupling.



Crowded conditions in an engine room required that this drive be employed to connect a new generator to the main engine. The belt that drives a countershaft at the left is mounted on top of the belt driving the generator.

Transmitting power through

Short-Center Drives

IN LAYING out a new installation, or revamping an old one, conditions frequently make it necessary to transmit power from one shaft to another when the distance between the centers of the shafts is unusually short and a change in speed is required. Sometimes the desire or necessity of conserving floor space demands the use of a very compact drive. In other cases obstructions in the way of building columns, other equipment, and so on, render it necessary to mount the driving and driven shafts close together. In any event, a problem in power transmission is presented that is often troublesome.

When belt drives are operated on short centers over pulleys that are of widely different diameters the arc of contact on the motor pulley may be small enough to produce very unsatisfactory operation. If uncorrected, a small arc of contact leads to excessive belt slippage, which in turn causes loss of power and speed and induces rapid belt wear. Sometimes an attempt is made to reduce slippage by running the belt under extra-heavy tension. This expedient may be more or less successful in reducing slippage, but it inevitably leads to short belt life and abnormal bearing friction and wear.

Without going into a detailed discussion of this problem and the methods of solving it, it may be said that belts of special tannage or treatment that increases the coefficient of friction, as well as various types of gravity idlers that increase the arc of contact have been successfully employed in overcoming the troubles encountered with short-center belt drives.

On the other hand, the installation of a chain drive or direct connection through a speed reducer will oftentimes prove to be the solution of short-center drive problems.

Intelligent selection of the equipment for a short center drive must be based on a careful study of the operating requirements and conditions. The best type of drive for one installation may not be equally well adapted to another one in which the conditions are different. Basically, the problem is not one of picking out a drive arrangement that is merely workable. As in the case of all power drive applications, the ideal to be aimed at is the installation of a drive that will best meet the requirements from the standpoint of giving the desired results with the greatest efficiency and reliability, and at the lowest cost for maintenance attention. This can be accomplished with certainty only when a thorough understanding of the operating requirements and a sound knowledge of the advantages and limitations of the various types of drives available are brought to bear on the problem.

Details of a few installations will be given below to show how short-center drive problems have been solved in a number of industrial plants.

R. SALMONSEN, *Mechanical Engineer, F. L. Smidth Co., New York, N. Y.*—When the problem of installing a generator unit in a plant already taxed for space was settled, a Lenix drive was selected for the in-

stallation in connection with a tandem-belt drive, as shown in the illustration on page 461. A drive of this type was used because the full width of the 52-in. face engine flywheel was already being utilized by belts, one being a 30-in. main lineshaft belt, shown in the right-hand corner of the illustration, and one 16-in. countershaft belt, shown toward the left side of the illustration. With this arrangement, the engine could be loaded to only about two-thirds of its rated capacity.

To utilize the full capacity of the engine, the layout required that the new 20-in. wide, 150-kva. alternator belt be driven from the main engine pulley, and underneath the existing 16-in. countershaft belt.

The belt stretch on the generator drive is automatically taken care of by the Lenix drive, a constant belt tension being maintained at all times. The large arc of belt contact and the compactness of the arrangement were particularly desirable as ample passageway, it will be noticed, is still provided. Incidentally, the efficiency of the countershaft drive was improved due to the higher coefficient of friction resulting from the leather countershaft belt riding directly on top of the leather generator belt.

H. F. WEBER, *Engineer, Link-Belt Company, Chicago, Ill.*— At the plant of the Illinois Wire and Cable Co., Sycamore, Ill., it was necessary to transmit power from a motor running at 695 r.p.m. to a draw bench whose speed of operation approximated 195 r.p.m. The difficulties encountered on this 150-hp. drive were the necessity for a large speed reduction and a short-center drive of 38 in. because there was no more room available between the motor and the driving shaft of the machine.

It was obvious that the drive equipment used in this installation would be subjected to the severest kind of service on account of the size of the drive, amount of power to be transmitted, and the short center distance between the shafts.

After a careful analysis of the problem we decided to apply a 17-tooth driving pinion on the motor and a 68-tooth driven gear on the bench, with a 1½-in. pitch, silent chain 12 in. wide as the drive connection. The drive was installed in 1922 and is still giving good service.

K. D. HAMILTON, *Mechanical Department, Geo. E. Keith Co., Campello, Brcckton, Mass.* — An interesting problem came up at our plant in connection with the drive for a large, slow-speed planing mill exhauster. The trouble that we had was caused by the extremely short center distance between the driving and driven pulleys.

First of all a chain drive operated from an 850-r.p.m., 100-hp. motor was selected for the job of driving the planer. This drive operated satisfactorily for only a comparatively short time. Evidently the very short centers and the peculiar conditions under which the exhaust fan was installed caused vibration to be set up in the chain and caused excessive heating of the motor bearings.

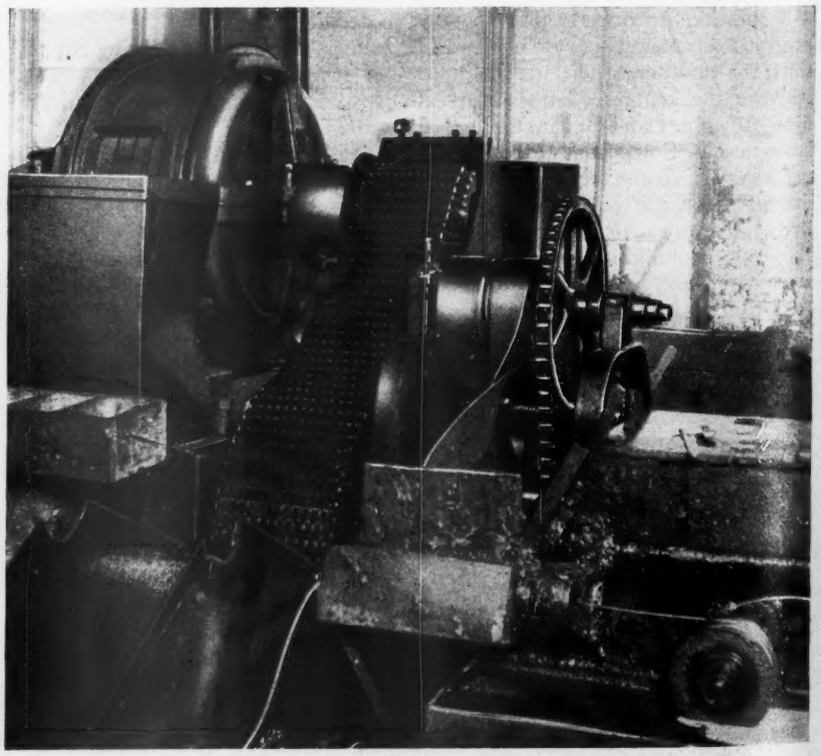
After considerable experimenting, it was finally decided to remove the chain and install a double belt 18-in. wide, although the pulley centers were only 6 ft. apart. This belt drive also proved to be unsatisfactory, for when the exhaust fan operated at full load, we experienced excessive slipping of the belt on the motor pulley, due to the small arc of contact. To overcome this difficulty an idler pulley was installed near the motor end of the drive.

This idler sufficiently increased the arc of contact on the motor pulley to prevent any slipping of the belt even when the motor was loaded to capacity. After the belt slipping trouble had been eliminated, all vibration of the motor disappeared and the motor bearings operated at their normal running temperature.

J. A. MARLAND, *W. A. Jones Foundry & Machine Co., Chicago, Ill.*—The management of a large steel fabricating plant recently decided to increase the productive capacity in one department by the addition of a machine in which one operation requires a very slow motion. This installation presented several interesting problems. One of these was the requirement that the drive be as compact as possible, as floor space was at a premium. The reduction ratio was 120:1 and it was necessary to drive two parallel shafts on the machine at low speed.

Other machines of the same kind that were installed several years ago are driven by a motor through two high-speed chains. The motors are mounted on sliderails and drive a countershaft through a high-speed chain. A second chain runs from the countershaft to a pinion shaft that engages with two large gears. These gears are mounted on parallel main shafts that turn at 5 r.p.m.

Although this drive arrangement gives the desired reduction in speed, considerable trouble is experienced on account of the short life of the chains. Operating conditions are severe and the average life of a chain is about 20 months. Naturally, this



This draw bench is driven by a 150-hp. motor through a Link-Belt chain operating on 38-in. centers.

On this application a speed reducer released about 70 per cent of the floor space required by the type of drive formerly employed.

This 120:1 ratio Jones reducer drives one of the machines in a steel fabricating plant. Two parallel, low-speed shafts on this machine, located on the other side of the wall, are connected by a short chain drive.

makes maintenance costs high. The amount of floor space required is also objectionable.

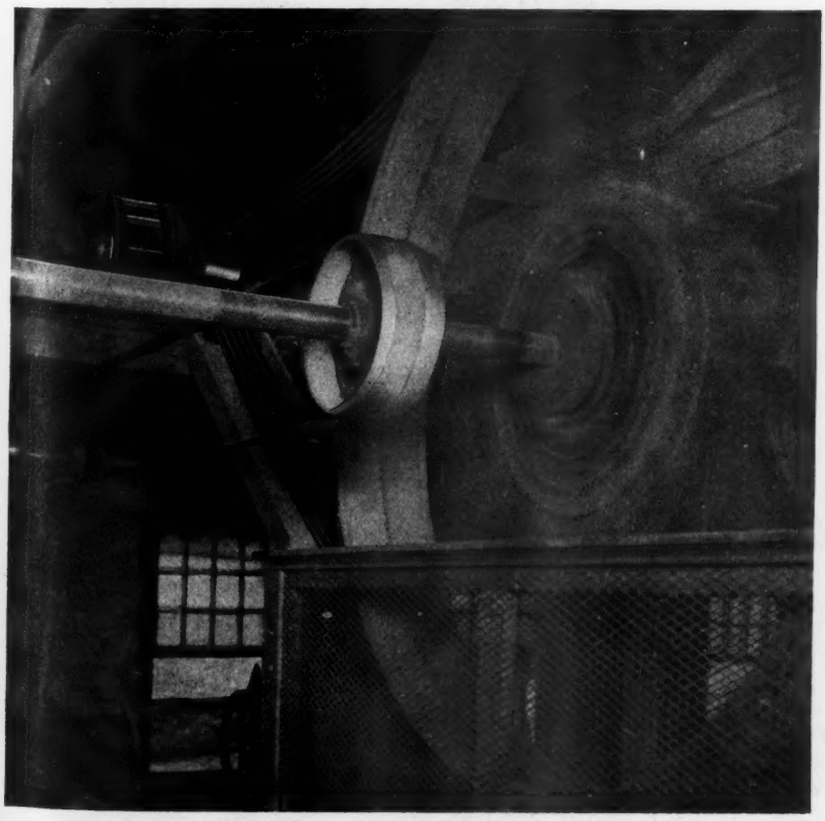
After a careful study of the requirements it was decided to install a Jones speed reducer to drive the new machine. This installation is shown in the illustration. The two parallel, low-speed shafts on the machine are connected, on the other side of the wall, by a short silent chain drive.

This drive has given entirely satisfactory service at low maintenance cost, and occupies only about 30 per cent of the floor space taken by the drive on the other machines, although it is of larger capacity.

J. L. DE RABOT, *Consulting Engineer, Alexander Brothers, Inc., Philadelphia, Pa.*—Some time ago the erection of an addition to the main building of a button factory in Connecticut made it necessary to cut several large passage-ways in the main building. To do this a few pieces of equipment and also one 12-hp. motor and a jackshaft had to be rearranged. It was eventually decided to put the motor up near the ceiling. However, considerable difficulty was experienced in properly locating the jackshaft. Direct drive was seriously considered, as the distance between the motor and main shaft drives was only 9 ft., and a large reduction in speed, which required a pulley ratio of 12:1, was needed in order to obtain 100 r.p.m. on the main lineshaft.

Space for a passage-way was obtained by replacing a jackshaft with this open belt drive operating on 9-ft. centers.

The pulleys on which this Tentacular belt runs are 7¼ in. and 90 in. in diameter respectively, giving a speed reduction of 12:1.

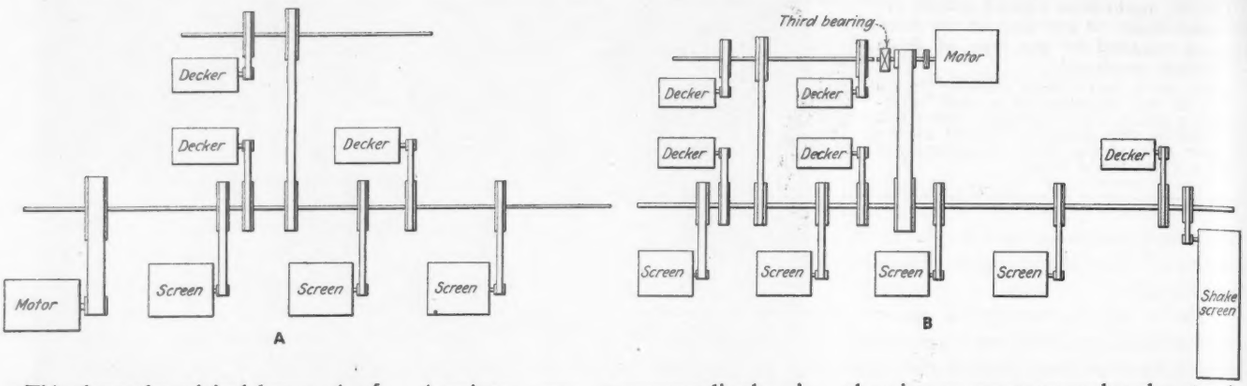


After investigating several different types of drives, it was finally decided to try an open belt drive, using a 7-in. Tentacular belt, as shown in the accompanying illustration. The driving pulley is 7¼ in. in diameter, and the driven pulley is 90 in. in diameter. No trouble has been experienced with this drive and it is giving much better satisfaction than the old, which included a jackshaft. The new short-center drive has made available space for the passageway.

H. E. STAFFORD, *Electrical Engineer, Provincial Paper Mills, Ltd., Port Arthur, Ont., Can.*—Of the various changes that have recently been made at our plant, the one that is described below required the most thought and effort.

In connection with our groundwood mill we originally employed three centrifugal screens, requiring approximately 17.5 hp. each and three deckers or washers requiring 5 hp. each. They were driven as shown at *A* in the accompanying illustration. A 125-hp., 514-r.p.m. wound-rotor induction motor that had previously driven a 1,700-lb. beater was available for the drive, and was belt connected to a lineshaft, which was about 60 ft. in length.

This motor was first installed at one end of the lineshaft, and connected to it by a 14-in. double leather belt. The load on the motor was about 75 hp. It was found impossible, however, to run the various machines at their proper speeds owing to the belt slippage due to the short center distance—14 ft.—between shafts. In order to prevent slippage it was necessary to tighten the belt to such an extent that there was excessive wear on the belt and also on the motor bearings.



This shows the original layout, *A*, of the drive for the ground-wood screens and, *B*, how the drive was re-arranged to overcome operating troubles.

Recently it was desired to drive from this lineshaft one more screen, which was then being driven by a 20-hp. motor, two more washers, and a shake screen. After considerable study and discussion the following changes in the layout of the drive were made.

The motor was shifted so that the drive came in the center of the lineshaft as shown at *B* in illustration. The belt width was increased to 24 in. and the distance between centers increased 6 ft., making a total of 20 ft. The motor was equipped with an outboard bearing, making a three-bearing arrangement. A larger pulley was placed on the motor, which allowed the speed of the various machines to be increased to the maximum.

After all the old as well as the new equipment was placed in operation, the load on the motor was found to be 130 hp. This represents only a slight overload, which the motor is able to carry with a rise in temperature of only 30 deg. above the room temperature.

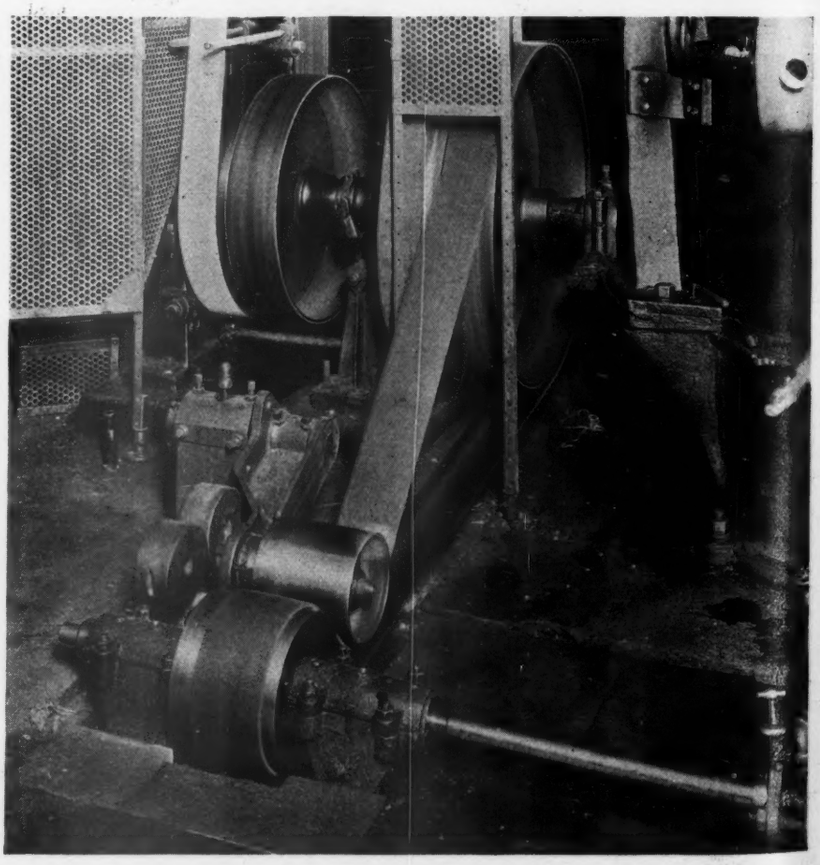
As the result of this change the production of screened ground-wood has been increased from 50 to 80 tons per 24 hr., and we have had no more belt trouble due to slippage or other causes.

STANLEY HASTE, *The Bird Machine Co., South Walpole, Mass.*—A great deal of trouble was experienced with the drive for a dye pump in a textile mill, due to excessive belt slippage. Slippage, in turn, was caused by the small arc of contact on the motor pulley. This was an open belt drive operated by a 15-hp. motor and in order to keep the pump going the belt had to be kept so tight that it was under a very abnormal tension. Friction in the bearings was correspondingly increased and because of the undue heating all of the bearings and the pump packing had to be watched closely, in order to avoid the necessity of shutting the pump down during working hours. Naturally the bearings and packing had to be renewed frequently. Furthermore the operating conditions were so severe that the driving belt had to be replaced about every six months.

In order to improve the operating conditions several changes were decided upon. First, the flanged pulley then in use was removed and a standard cast-iron pulley was installed in place of it. Then, after a new belt was put on, a Pulmax drive was installed to increase the arc of contact on the small pulley. Increasing the arc of contact will frequently improve the operating efficiency of a belt that is well loaded, regardless of whether it is operating on a long or short center distance.

When the arc of contact is increased a belt can carry its load with less tension on it. Consequently, it was found possible to reduce the tension on the dye-pump belt to the point where bearing heating and wear were entirely normal. No further trouble has been experienced with this installation.

Increasing the arc of contact by the use of a Pulmax drive made it possible to reduce the tension on the belt and thus eliminate both belt and bearing troubles.



Study Your Power Transmission Problems

By F. H. WILLARD
President,
Graton & Knight Company, Worcester, Mass.

ALL the factors involved in the transmission of power are constantly changing, and have been changing for the past twenty-five or thirty years; hence a principle that is applicable today may not be applicable tomorrow. For this reason, a study made for economic reasons when a plant was erected is not satisfactory as a guide to all future action. It is necessary for the manufacturer to keep his problem in mind constantly, and watch for new developments, if he is to keep his methods thoroughly up to date.

F. H. WILLARD

The development of the motor and of machine tools has been making rapid strides, and will continue to progress. At the same time, manufacturers of the older forms of transmission equipment are constantly improving their product, and these improvements should not be left out of consideration, nor disregarded in the light of conditions which existed in the past. Competition between the various forms of transmission equipment will tend increasingly to spur all manufacturers thereof to greater endeavors, in order that each may maintain or increase his own standing in the field. The off-hand installation of forms of transmission equipment, which at first glance may appear to be panaceas for all kinds of transmission difficulties, should be discouraged. No such panacea has as yet stood the test of universal and continued application. The very nature of the transmission problem, involving as it does widespread and often conflicting phases, indicates the impossibility of the development of any such cure-all.

The cost of power transmission, however, has been given little or no scientific study. Sales talk has, in many cases, brought about expensive changes that have resulted in a higher, rather than a lower, cost of transmission. This action has many times been taken without any disposition to investigate the cost of the older types of transmission, and improve them, as they may be readily improved.

The question of power transmission is worthy of a real, scientific study, commencing with the equipment already in the plant and studying methods of improving it, as well as proper installation and upkeep. Power transmission equipment is too frequently allowed to run on and on without any attention other than oiling of the bearings; whereas, if a suitable organization had charge of this equipment, and it were given the same careful attention that many of the production machines are given, thousands of dollars would be saved in power consumption, and thousands more would be made in increased production. There is a proper place for every form of power transmission equipment that is on the market, but no equipment of any kind should be installed without first studying carefully its adaptability to the job. Any amount of study and engineering skill is displayed in selecting the proper power unit and the proper production machine, but little or no study is given to the selection of the best form of transmission between the two.

In short, the determination of the proper transmission equipment should include a comparison of the power consumption by various units. To make this comparison, technical and scientific research is absolutely required. If the study is to produce accurate results, it should include:

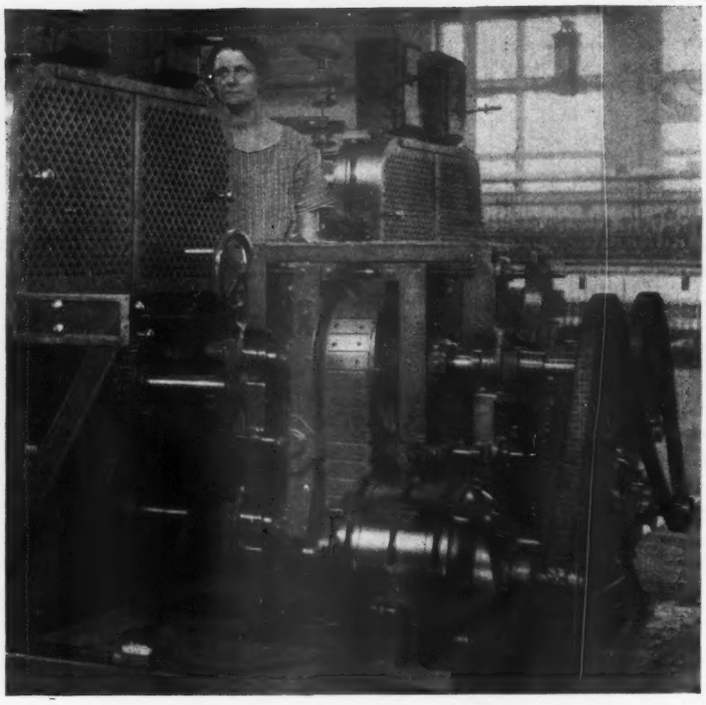
The original cost of the drive installation, so that the merits of all drives may be considered from the standpoint of the individual plant. There should be comparisons of the frictional losses, upkeep costs, frequency of replacements and relative costs and of the probable amortization values.

It is necessary to make studies of the ease with which changes may be made should conditions warrant the adoption of another system, and the facilities for quick repair in case of breakdown, with consideration of savings that might result from elimination of abuse of the equipment. Many other points will need consideration from the standpoint of the individual plant or industry.

To the end that complete and impartial studies may be made, without prejudice for or against any particular form of equipment, an organization known as the Power Transmission Association has been formed, which will comprise the leading manufacturers in every branch of this field. It has a capable board of engineers, representing, not the transmission equipment manufacturers themselves, but a cross-section of the industries that use this equipment, and they will make exhaustive studies.

Buyers of transmission equipment who feel that they require the assistance of this association—and it is my opinion that most of them do require it—are invited to communicate with the secretary, Mr. W. S. Hays, Drexel Building, Philadelphia, Pa. No obligation is involved.

This is one of five twisters in a New England French-worsted mill that are equipped with two Lewellen variable-speed transmissions driven by 5-hp. motors.



These transmissions make it possible to obtain any speed between 750 and 8,000 r.p.m. required by the size and twist of the yarn that is being made.

How Problems in

Variable-Speed Operation

have been solved

IN THE operation of many types of production machines, it is necessary to provide some satisfactory means of varying the speed at which the machine is driven. Textile machinery is a well-known example of a class of equipment that frequently requires to be driven at different rates of speed. For example, it is necessary to start silk throwing and winding frames slowly and gradually bring them up to speed in order to avoid breakage of the fibers.

A requirement encountered in several different industries is that of winding paper, cloth, wire, linoleum, or other flexible material on to rolls and gradually decreasing the speed of the roll as it increases in diameter. In other words, it is necessary to regulate the speeds so that the roll will always wind the same number of yards per minute.

In some of these cases the material is coming from a production machine at a given number of feet or yards per minute. The winder must synchronize exactly with the production machine. In other instances the goods or material is wound from one roll to another for the purpose of inspection or for some finishing process.

It is also necessary, or desirable, to vary the speed of assembly conveyors, which are widely used in automobile plants and in various industries, in order to meet varying production demands or to give the men a chance to become "warmed up" in the morning before maximum production is attained.

Briefly, variable speeds may be obtained either electrically, by the use of a variable-speed motor and suitable control, or mechanically, by the use of some simple device such as step or cone pulleys, or by employing what are commonly known as variable-speed transmissions. These are of two general classes or types.

One of the well-known types of mechanical variable-speed transmismission consists essentially of two pairs of movable, cone-faced disks mounted on parallel shafts and connected by some form of belt, which drives from one pair of disks to the other. Levers are provided for moving the disks so that as one pair approaches the other pair separates. The diameters of the disks are thus changed and the speed ratio modified. Slight shifting of the disks makes it possible to obtain a wide range of speeds in a large number of steps.

In another type of mechanical variable-speed transmission that has recently been developed, change in speed is obtained by shifting the position of rollers on a cone-shaped race.

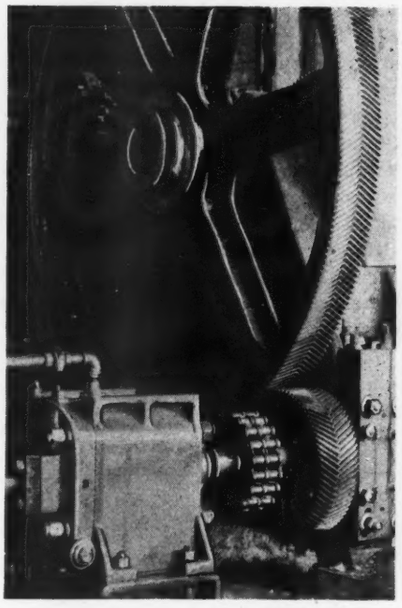
Several makes of hydraulic variable-speed transmissions are also available. In general, these consist of a pump, operated at full speed by the driving motor, that can be adjusted to force a varying quantity of liquid, usually oil, into a companion unit, which is thus driven as a motor at a varying speed, that depends on the quantity of liquid received. Most of these hy-

draulic units can be adjusted to deliver speeds ranging from zero to the maximum speed of the pump unit. Also, the low-speed unit can be made to operate in either direction, although the pump unit is driven at a constant speed in one direction.

The problem of obtaining a sufficiently wide range of speeds, and controlling these easily and accurately, is oftentimes a difficult one to solve satisfactorily. Details of how this problem has been solved in various installations are given below.

D. R. FRANCIS, *Chief Engineer, The Waterbury Tool Co., Waterbury, Conn.*—In the manufacture of paper it is necessary to vary the speed of the machine within wide limits. This requirement presents some practical difficulties that have been the subject of a good deal of study. The manner in which we solved one interesting problem of this character is indicated in one of the illustrations, which shows an installation of one of our hydraulic variable-speed gears driving the variable-speed line of an 86-in. paper machine at the Parsons Paper Co., Holyoke, Mass.

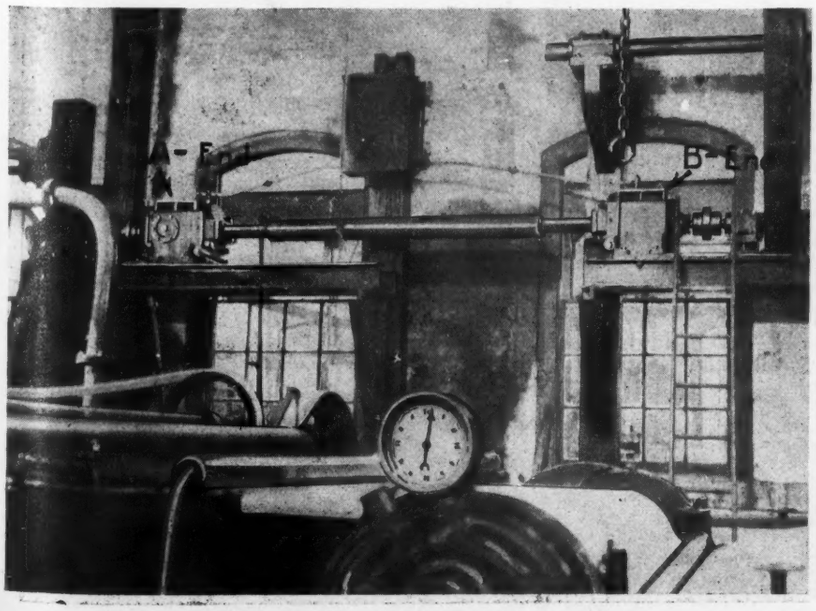
The variable-speed line of a paper machine extends the entire length of the machine. The several sections of the machine are driven by belts over cone pulleys from this variable-speed line. The slight difference in speed to compensate for stretch or shrinkage of the paper between sections is taken care of by the location of the belts on these cone pulleys. The speed of the variable line, however, is varied over a wide range corresponding to the different weights of paper manufactured. For a heavy paper



This shows a hydraulic variable-speed gear on the variable-speed line of an 86-in. paper machine.

the speed is slow; for a light paper it is high. To convey some idea of the range of speeds necessary we might mention that on one machine for which we have furnished a drive the paper made varies from a tissue of about 11 or 12 lb. to a bristol board, running as high as 185 lb. A very considerable portion of this change in weight is accomplished by varying the speed of the paper machine. This requires a corresponding variation in the speed of the variable-speed line.

The range of speeds on the variable line shown in the illustration is approximately 10 to 1. The A- or pump-end of the hydraulic variable speed gear is located at the left side of the illustration, and is driven by a silent chain from the constant-speed line, running along the floor. This constant-speed line, in addition to driving the A-end, drives all of the constant-speed equipment, such as pumps, screens, shakes, etc. There is a very decided advantage in being able to use one source of power for operating both lines of the paper machine, as it makes possible one large instead of two small power units, thereby reducing both the initial expense and maintenance.



Here is an application of a hydraulic variable-speed gear to a veneer lathe.

The A-end of the variable speed gear is driven at a constant speed. The volume of oil displaced by the pump is proportional to the setting of the control shaft, and the displacement of oil governs the speed of the B-end. The B-end of the unit is located at the right, and drives by a silent chain the variable-speed line which is overhead, the speed of the variable line ranging from 0 to about 165 r.p.m.

Piping is used to connect the two units, and this piping is jacketed for cooling purposes. Some cooling is necessary on any installation running in continuous service.

Another unique variable-speed application can be seen in the other illustration, which shows an installation made in a Western veneer mill. In this case the B-end of the hydraulic variable-speed gear is direct-connected through herringbone gears to the main spindle of the veneer lathe. By this means the speed at which the log is rotated is governed over a very wide range. By connecting the control shaft of the A-end to a cam on the end of the log the speed of rotation can be automatically governed by the size of the log. As the log is reduced in diameter its speed of rotation is increased so that veneer is cut at a constant cutting speed.

It has been found that in this way it is possible to cut the logs to a very much smaller diameter than was originally possible, resulting in a very considerable reduction in waste. Also, due to the fact that the cutting speed is constant the production is greatly increased. It has been found possible to use profitably logs that were much too small to be cut by previous methods. This has made possible the use of timber that could not be economically used before, and due to the fact that the small trees are usually of a better grain and sounder, better veneer is produced.

E. W. SEEGER, *Engineering Dept., The Cutler-Hammer Mfg. Co., Milwaukee, Wis.*—The use of powdered fuel in boiler plants has given a decided impetus to the use of automatic control and has presented some interesting problems in variable-speed operation.

One of the difficult problems in connection with an installation of this kind is the design of satisfactory fan controllers, particularly on the induced draft, which requires a larger unit than the forced draft.

The illustration shows the induced draft fan controllers recently installed by a large utility company and used in connection with four two-speed, 550-hp., 450/900-r.p.m. slip-ring motors. Sixty speed points were required, with a total range in speed of 9 to 1.

The equipment for one fan is shown here set up on the test floor. The master unit *A* is supplied with a pilot motor drive responsive to changes in steam demand. This drive in turn controls the secondary resistance drums *B* and *C* by means of the chains shown. Electrical interlocks are provided in the drums which allow closure of the air-break, electrically-operated primary circuit breaker only when a sufficient amount of resistance is inserted in the motor secondary.

The switch *D* is a multi-pole, two-position, motor-operated device used for transferring the motor primary and secondary resistance connections from low to high speed. The pilot motor of the transfer switch drives a cam which moves through 180 deg. at each operation, opening one set of motor contacts and closing the other. The motor drive is supplied with a handwheel for unmeshing the gears and a handle for emergency manual operation.

In order to avoid any possible motor trouble at high speeds where the load is heavy, the resistance is balanced on the last five controller points. Contacts on drum *C* control the motor-operated drum *E*. A small motion of controller *C* causes an extended and rapid motion of drum *E* which is stopped when the contact fingers are making full contact on their related segments.

The total speed range of the equipment is 9 to 1. A 2 to 1 reduction is obtained by reconnecting the motor windings, and the remainder by secondary resistance in the low-speed connections.

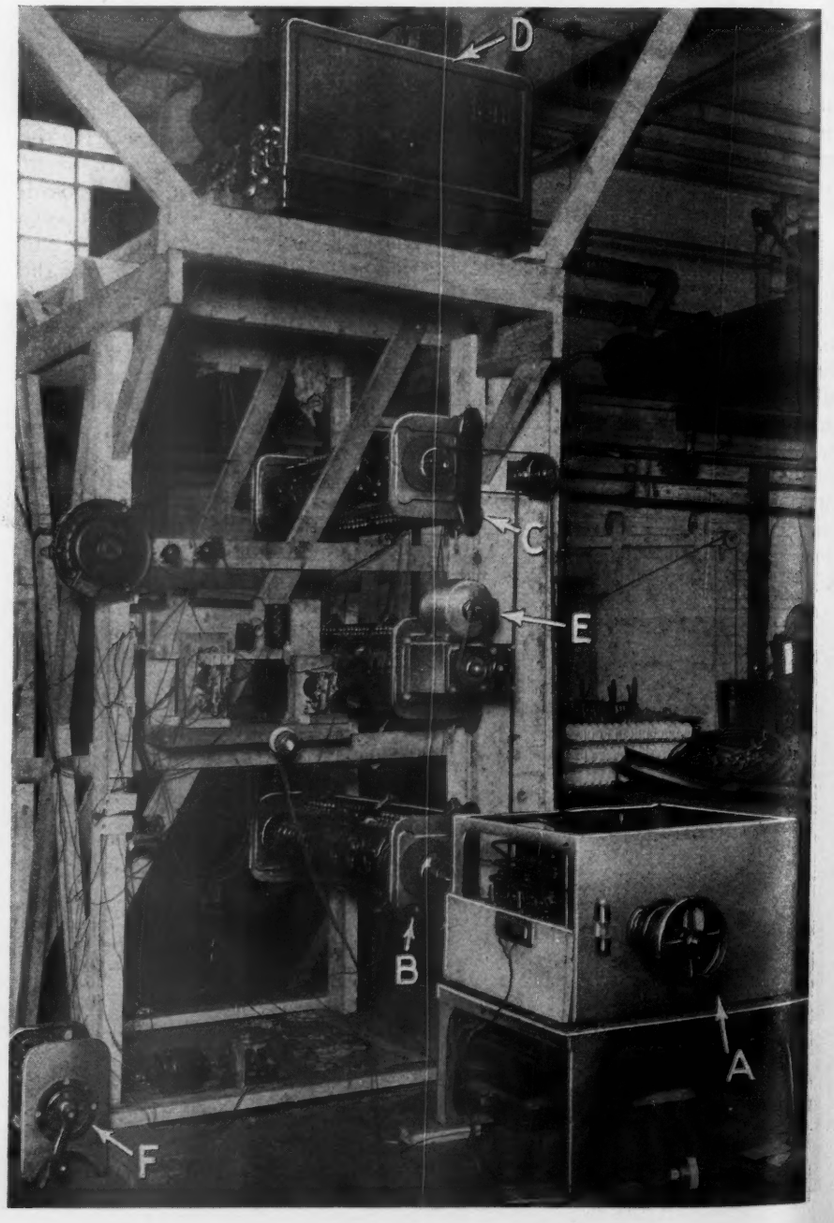
With all of the speed-regulating resistance in circuit, the starting torque is limited and the motor-operated drum *F* is provided to insure starting. This drum makes one-half revolution when the equipment is energized, short-circuiting a portion of the regulating resistance and reinserting it when the motor is under way. If the fan motor stalls at any time on the low speed, drum *F* operates and causes restarting.

In operation, when a boiler is placed in service, the demand for steam causes the master unit, *A* to start and open the dampers, thus utilizing natural draft. On further demand for steam, the master unit starts to revolve drum *B*. Drum *F* and the primary circuit breaker then operate, starting the motor. As drum *B* revolves, secondary resistance is short-circuited and the motor speed increases.

Just before drum *B* reaches its limit of travel, drum *C* also starts to move, interrupted gears in unit *A* being used to start and stop the drums at the proper points. On the last point of drum *B* a contact is made for the pilot motor on the transfer switch *D*, which opens the low-speed primary connections, inserts the high-speed secondary resistor and closes the high-speed connections.

Further movement of master unit *A* causes the high-speed drum *C* to revolve and short-circuit the secondary resistance. As the fan approaches maximum speed, drum *E* is brought into play and the resistor is balanced on the last few points.

Induced draft fan controllers for two-speed slip-ring motors, giving a speed range of 9 to 1.
The illustration shows this Cutler-Hammer installation on the test floor.



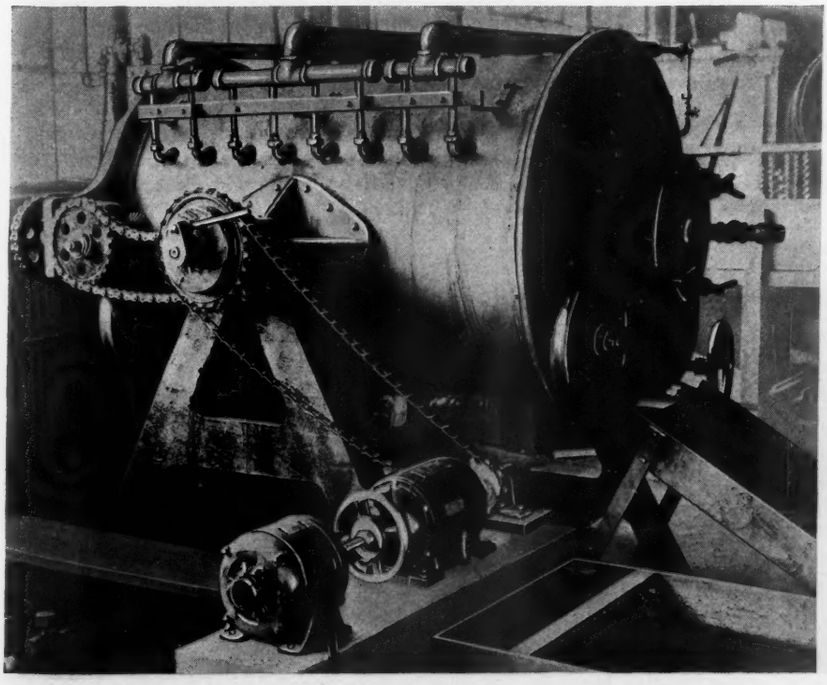
If the demand for steam decreases, the reverse operation takes place. The resistance in the high-speed winding is first increased until the speed is slightly below the synchronous speed of the low-speed connection. In its final position drum *C* causes the transfer switch to operate and connect the motor for low-speed operation. Drum *B* then inserts secondary resistance and reduces the fan speed. Eventually, drum *B* is stopped in its final position and further operation of unit *A* causes the motor to stop.

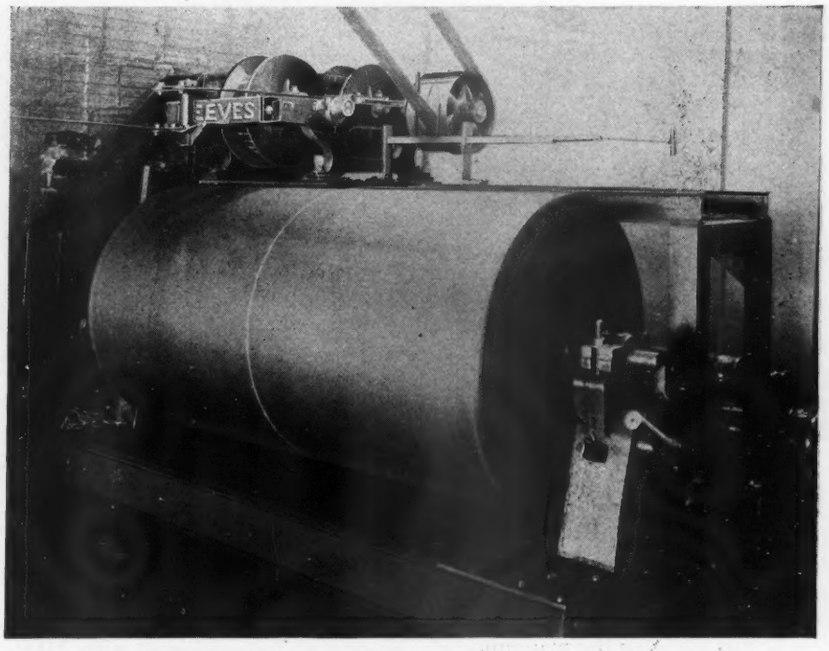
C. H. ADAMSON, *Stephens-Adamson Mfg. Co., Aurora, Ill.*—In the successful operation of a carburizing furnace it is often necessary to vary the slow rotation of the drum within a range of from one to five revolutions per minute, approximately. To facilitate this control it is highly desirable to be able to change the speeds at will and with minimum effort on the operator's part.

The illustration shows an installation in which the constant-speed electric driving motor shown at the left is direct-connected to a JFS variable-speed transmission which in turn drives the rotating mechanism for the revolving drum through a chain.

The speed variation is secured through the JFS speed unit which gives the desired control of the rate of rotation of the drum by manipulation of the small handwheel, that can be seen mounted between the motor and the variable-speed transmission.

Variable-speed drive for a carburizing furnace.
The revolving drum is driven by a constand-speed motor through a JFS. variable-speed transmission.





Reeves variable-speed transmission driving a winder in the plant of the Cott-a-lap Co., Somerville, N. J.

R. F. REEVES, *Reeves Pulley Co., Columbus, Ind.*—In the textile industry, as well as in others, there are a number of applications that require variable speed. One example of this is found in winding operations in which material is wound on a roll as it comes from the machine, or is transferred from another roll for one purpose or another. The problem of securing a uniform peripheral speed of a roll of cloth or other material that is constantly increasing in diameter, is an interesting one.

The illustration shows a Reeves variable-speed transmission in operation in the plant of the Cott-a-lap Co., Somerville, N. J. In this case the extended lever type of transmission is used, in which a follower roll bears against the roll of goods. This follower roll is connected to the extended lever of the transmission. As the roll of goods increases in diameter the follower roll is carried outwardly with it and in so doing moves the extended lever so that it gradually decreases the speed of the transmission, which, of course, controls the speed of the roll. When the roll is completed a balance weight returns the extended lever to its original position ready to start winding another roll.

Production on a roll equipped with a variable-speed transmission can be greatly increased over the volume possible where the peripheral speed varies in accordance with the increasing diameter of the roll. As an example, in one installation the operator has found it possible to fill the roll in 7½ min. whereas it formerly required 16 min. This represents a saving of approximately half of the time required heretofore.

The same general problem has been solved in several other cases by the use of our electrical automatic transmission. In this type of installation the automatic switch has an operating lever that is connected to a follower roll.

Operating pulpit showing control board for 21-in. continuous sheet bar and skelp mill.

R. H. ROGERS, *Industrial Engineering Dept., General Electric Co., Schenectady, N. Y.*—Many problems in variable-speed operation are encountered in steel mill service. Not only are the requirements exacting, but in this industry the magnitude of the equipment and the amounts of power handled are of such magnitude that careful attention must be paid to efficiency of operation and many other details.

Some interesting and unusual problems were recently met in designing the control and drive equipment of a 21-in. sheet bar and skelp mill consisting of ten 2-high stands in line for continuous rolling. The requirements were somewhat complex in that although the equipment could be loosely grouped into roughing, intermediate, and finishing stands, the work might be completed in as few as three stands or any other number up to the whole ten.

The roughing and intermediate stands, seven in all, in groups of three and four respectively, required adjustable-speed operation, but not of particularly fine adjustment. The three finishing stands were required to operate independently through a wide speed range capable of rapid fluctuations under rapid and precise control, because of the high speeds attained together with the necessary control of the loops of hot metal between stands.

It was decided to drive the roughing and intermediate stands with induction motors. The first required a 3,600-hp. motor at 290 r.p.m. down to 1,940-hp. at 156 r.p.m. The second required a 7,500-hp. motor at 250 r.p.m. down to 4,040 hp. at 134 r.p.m. Rheostatic control would result in enormous energy losses because of the great power and speed range required. Again, the power factor of slow-speed induction motors is naturally very poor and means for its improvement is required.

The required speed range and quality of control as to rapidity and precision indicated direct-current motors for the three finishing mills; hence they were powered with 2,000-hp. 85/165-r.p.m., 600-volt motors.

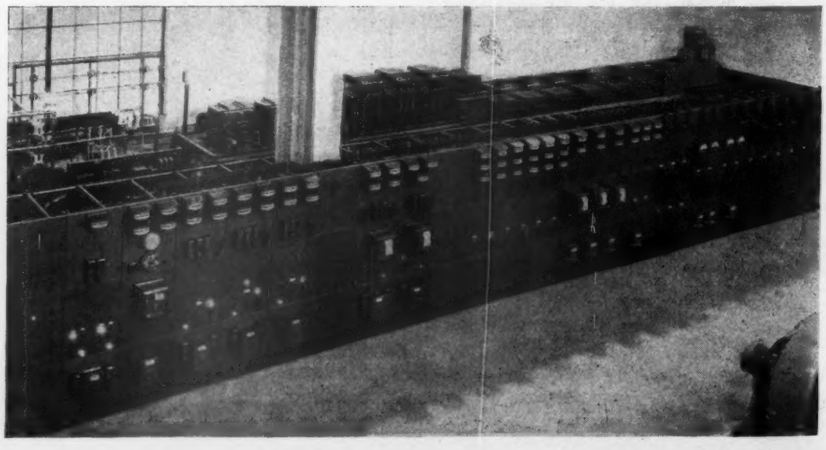
The power supply is 2,200 volts, three phase, 60 cycles and the induction motors are directly connected to this supply. Three synchronous motor-generator sets were supplied: each consists of a 4,400-kva. synchronous motor driving two 1,700-kw., d.c. generators. Only three of the generators are required to drive the three finishing stand motors which are controlled by the Ward Leonard system: that is, by generator voltage control. That leaves three d.c. generators to be accounted for later.

The induction motors on the roughing and intermediate stands are controlled by a modified Kraemer system. The normal Kraemer system of speed control for an induction motor transforms the slip energy of the induction motor to d.c. power through a synchronous converter and then applies that power to the induction motor shaft by means of a d.c. motor. In some cases the d.c. power is used to drive a motor-generator set to return a.c. power to the line.

In this installation it was found expedient to return the d.c. power (derived from the induction motors by way of the synchronous converters) to the synchronous motor-generator sets in order to relieve the synchronous motors of at least part of their loads coming from the finishing stand motors. The partly-loaded synchronous motors thus furnish a substantial amount of leading kva. for improving the power factor of the whole plant. Power factor of the individual induction mill motors is improved by varying the field excitation of the synchronous converter to advance the phase angle of the counter-emf. The power factor of this mill is 97 per cent at full load and maximum speed. At full load and minimum speed it is 94½ per cent. At less than full load at any speed the corrective kva. is still greater.

The speed of the mill induction motors is adjusted by the apparently round-about method of varying the field strength of what are now the d.c. motors on the synchronous motor-generator sets. By strengthening the motor field the counter-emf. is increased and acting through the converter it bucks down the secondary voltage of the induction motor and hence causes it to slow down. In this way any variation in the relatively small field current of the d.c. motor results in an immediate, corresponding speed change in the 3,500- or 7,500-hp. induction motor as the case may be.

This shows the switchboard for the electrical equipment of the 21-in. continuous sheet bar and skelp mill.



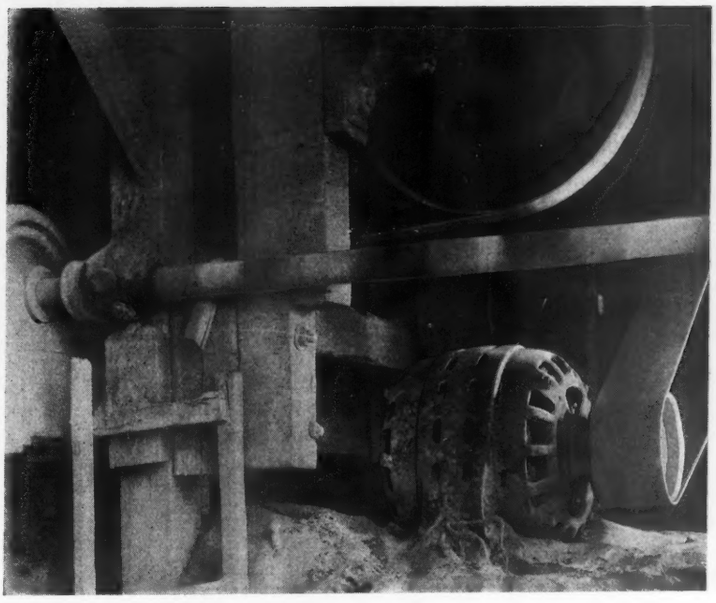


Fig. 1—A typical example of power transmission where much dust and foreign matter is present. Under such conditions the utmost care is required in the selection of suitable lubricants.

Lubrication

of power transmission equipment

By ALLEN F. BREWER
Mechanical Engineer, The Texas Co., New York, N. Y.

IN THE operation of industrial plant equipment, bearing lubrication is a matter of prime importance. As a result, the selection of lubricants to suit the system of lubrication provided and the prevailing operating conditions should be undertaken in a most careful manner.

It can be appreciated that adequate lubrication is an absolute necessity for the efficient transmission of power. Abnormal wear of bearings may very easily cause pounding of shafting, with serious losses in efficiency due to the natural increase in friction. This would be indicated by an increase in bearing temperatures.

To discuss intelligently the subject of lubricants it will be necessary to consider for a moment the several methods most commonly used in the average plant for lubricating bearings. For this purpose these are discussed from the particular angle of their lubricating requirements.

With devices such as ring, chain and collar oilers, the lubricant is continually carried to the bearing surfaces from a reservoir which is part of the bearing housing. The distributing element which dips into the oil, rides on the shaft and as it rotates it carries with it a continuous supply of fresh oil.

To insure effective lubrication it is important that the reservoir be of adequate capacity to give the oil ample opportunity to rest, thereby making possible not only the settling out of sediment and other foreign matter, but also cooling to the requisite degree. As a rule the only way in which the oil in such a system is kept at the proper temperature is by radiation of heat from the exterior surfaces of the reservoir or lower part of the housing.

When the reservoir is of apparently insufficient capacity an auxiliary reservoir can oftentimes be installed. One way in which this can be done is to tap a hole and insert a short length of pipe into the lower part of the bearing, plugging the bottom end, of course, with a cap. Such a device has an added advantage in that it also acts as a collector of dirt or other foreign matter.

It is important to remember that oil which is carried to the top of such a bearing must be taken care of and returned to the reservoir as rapidly as it is delivered by the oil distributor. If this is not possible, oil will tend to accumulate in the upper part of the housing and ultimately be forced out of the bearing clearance spaces. In the case of an electric motor this is detrimental to the coils. In fact, certain authorities contend that in the steel industry, for example, oil-soaked insulation is a prevalent cause of motor troubles.

Loss of oil in this way, not to speak of other troubles, may also arise if the oil is carried at too high a level in the well, or if the ring or chain rotates at too high a speed. This will cause a splashing and churning of the oil, with the result that wherever there is any windage or draft through the bearing, the oil spray may be carried off.

To prevent the possibility of such action certain designs call for the use of baffles, throwers, or labyrinth packing. Such devices in particular prevent direct circulation of air from the outside and through the bearing. In company with proper grooving of the bearing metal to permit ready dis-

tribution and return of the oil, they are regarded as adequate assurance that the latter will function as intended and not find its way out of the bearing to cause motor trouble, or damaged goods, in the case of line-shaft bearings.

Most effective lubrication by means of such systems of lubrication is attained under normal temperature conditions by the use of a high-grade, straight mineral oil of approximately 150 to 200 sec. Saybolt at 100 deg. F. Before deciding on the viscosity of the oil to be used, the bearing construction should always be investigated. Oftentimes if oil returns are too small they may become clogged, causing heavier oils to overflow.

In view of the fact that such bearings may frequently be called upon to function under low temperatures, an oil with a low pour test should be chosen whenever possible. If this is approximately 0 deg. F., the oil will generally function satisfactorily. It must be borne in mind, however, that higher temperatures will oftentimes require additional viscosity to resist the thinning action of heat. Under such conditions, an oil of from 300 to 400 sec. viscosity or even higher should be used, depending upon the operating viscosity desired at the prevailing temperatures.

In brief, viscosity is a measure or indication of the relative fluidity of an oil at the specific temperature of test. It might otherwise be stated as that property possessed by an oil by virtue of which its flow is retarded due to the resistance offered by its component particles or molecules in moving past each other. Viscosity varies inversely with temperature. As a result, the higher the temperature the more fluid will an oil become.

It is, therefore, important to note the operating temperature when selecting an oil for practically any type of bearing or lubricator. For the purpose of standardization 100 deg. F. is frequently taken.

The term Saybolt refers to the type of testing device. This measures the time in seconds required for a certain volume of oil to flow through an orifice which is of standard size. When an oil is, therefore, referred to as having a Saybolt viscosity of, say, 300 sec. at 100 deg. F., it means that at a uniform temperature of 100 deg. F. 300 sec. will be required for 60 cubic centimeters of the oil in question to flow through the orifice of the Saybolt viscosimeter or viscosity-testing device.

Lubrication of Anti-Friction Bearings

From a lubrication point of view, ball bearings can be served either with oil or light grease according to the design of the bearing housings. Roller bearings will also function with oil or grease lubrication, but prior to the selection of a lubricant it is essential to study the type and construction of the rollers, as well as the design of the housing.

As a general rule, ball and roller bearings occupy a minimum of space, and require lubrication, inspection, and cleaning at very infrequent intervals, regardless of their type or service classification.

Anti-friction bearings involve rolling contact, as compared with plain bearings wherein sliding contact occurs. In ball bearings this rolling contact is that of a theoretical point over a given surface. Roller bearings, however, involve theoretical line contact between the journal or shaft element and the outer raceway. Their construction involves a set of perfectly spherical balls or an arrangement of solid or flexible rollers. The latter are cylindrical in shape, the distance between the inner and outer raceways being uniform throughout the length of the roller. Solid rollers, on the other hand, may be either cylindrical or tapered according to the type and design involved in their construction.

Regardless of the design of the rolling elements, however, these elements must be carried or housed in more or less the same way, using containers in the form of raceways and cages. The inner race fits on the shaft, the outer being held by the motor or hanger frame according to the type of installation. Between them are located the rolling elements. These are kept in their proper positions with respect to the races, and to each other, by the separator, cage or retainer. Rotation of the shaft sets up a rotary motion between the rolling elements and the respective inner and outer surfaces of the raceways.

The purpose of lubrication, of course, is to make rolling as easy as possible. To facilitate this, however, all the surfaces (which are highly polished) must be in as perfect condition as practicable. As a result, the lubricant must serve the dual purpose of both lubricating and protecting these surfaces against rusting, corrosion, pitting or abnormal wear. Minimum clearance, of course, of the parts, aids the proper functioning of such bearings, for any play between the component parts would tend to set up a certain amount of pounding which would be detrimental to effective operation. In brief, all motion must be as nearly akin to perfect

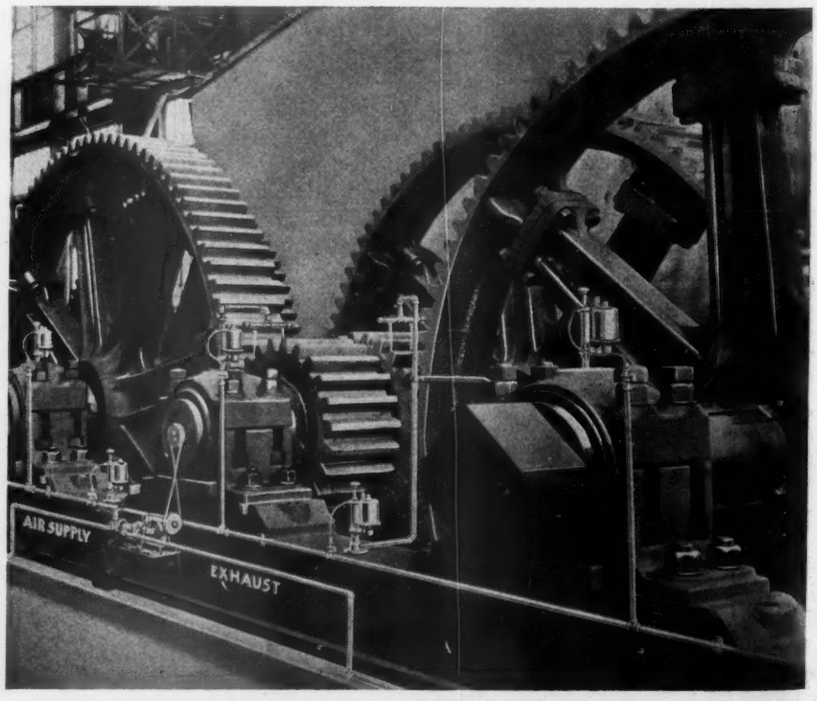


Fig. 2—Automatic lubrication is used on these exposed gears.

A comparatively heavy-bodied gear lubricant is used under air pressure. In this way all parts can be lubricated simultaneously at a saving in labor and economy in the use of lubricant.

rolling as possible if such bearings are to function as intended.

Experience has proved that as light a lubricant should be used as can be successfully retained in such a bearing, considering of course, the temperatures and pressures involved. In many installations, notably on machine tools, as brought out at the recent meetings of the American Society of Mechanical Engineers at New Haven, Conn., an oil of comparatively low viscosity will be best.

In this regard, ball bearings are claimed to involve less friction which is to a certain extent due to the fact that there is little or no end thrust involved. As a result the lubricant in such bearings serves more nearly the purpose of acting as a metal-protecting medium. In view of this fact, and to reduce the possibility of the development of abnormal internal friction within the lubricant, it is advisable to pay careful attention to the oil level. Certain authorities contend that submergence of approximately one-half to three-quarters of the lowest ball will be sufficient. It is, however, important to remember that contrary to the principles of plain bearing lubrication, the oil in an anti-friction bearing plays no part as a coolant. Therefore, a large volume of oil is a detriment rather than an advantage.

Lubrication of roller bearings by means of oil is subject to much the same conditions as stated in connection with ball bearings. Where end thrust may develop to an appreciable extent, due to difficulty in keeping the rollers in alignment, or where pressures or temperatures may be high, it will be conducive to better lubrication if somewhat heavier oils are used. On such bearings the use of straight mineral lubricating oils of as high as 750 sec. Saybolt viscosity at 100 deg. F. may be advisable. Even mineral cylinder oils of a high degree of purity may be necessary under conditions of extremely high duty, pressure, or temperature. The selection of heavier oils for roller bearing lubrication, however, should be carried out with the utmost care for it is possible to over-estimate the conditions of operation with the result that an excess of internal friction may be developed. Bearing temperatures in particular should be carefully observed.

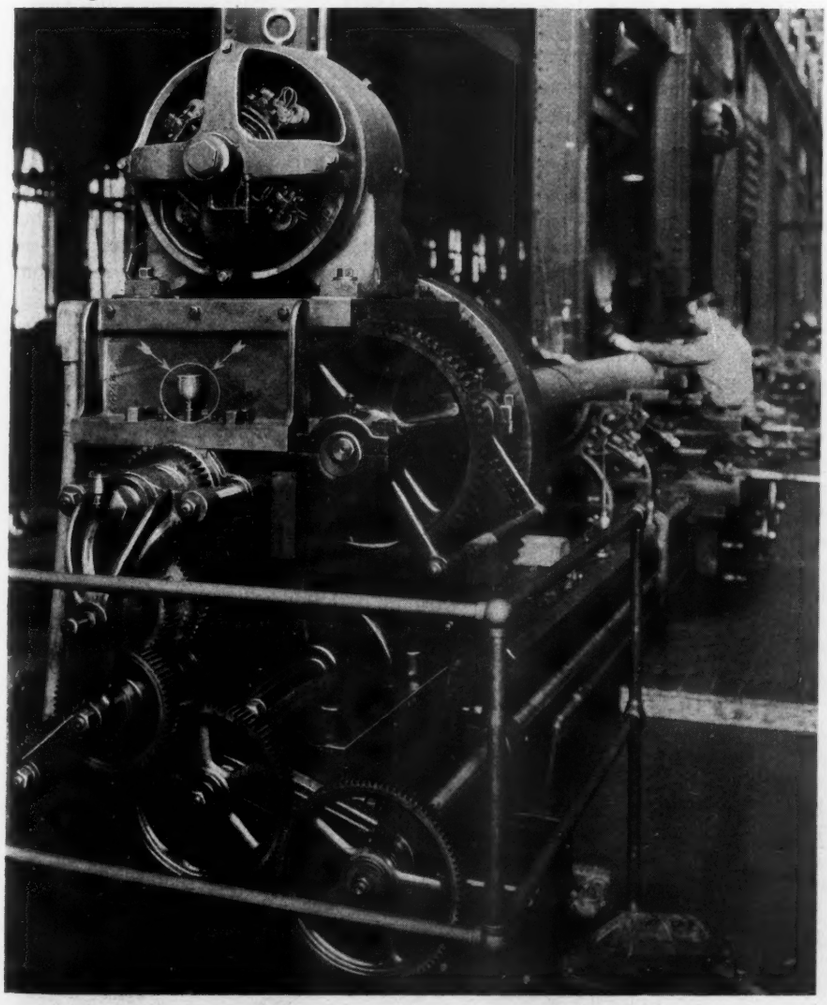
The use of grease, in turn, will usually be advisable wherever there is a possibility of oil leakage, or under dusty conditions or where there is an excessive amount of dirt or dampness as shown in Fig. 1. Greases furnish better seals against the entrance of dust, dirt, and moisture, thereby serving to protect the polished surfaces of the bearing elements in a very satisfactory manner. Greases also can be very much more effectively retained in a non-oiltight housing; on the other hand, dirt or grit that finds its way into a grease-lubricated bearing has no means of settling out. It will therefore, be held in suspension, and carried through the bearing elements continuously, ultimately giving rise to more or less wear.

Greases that are comparatively soft in consistency will normally meet average operating conditions where the lubricant must readily cover the entire surfaces of the balls or rollers and not tend to channel in the housings or raceways, as might occur with more viscous products of this nature which would have less tendency to flow. On the other hand, where high temperature may prevail, as for example, in the case of certain steel or cement mill equipment, it may be necessary to resort to greases of greater body to withstand the thinning-out effects of heat, and to prevent any possibility of foreign matter getting into the bearing.

Greases for anti-friction bearing lubrication should be as free from acid-forming substances as possible, in order to insure adequate protection of the highly-polished metallic surfaces. In effect, this involves perfect neutrality, chemically and of course, the absence of fillers. It must be realized that the presence of any material that might give rise to oxidation and the development of free acidity, or to decomposition or settling, is always a detriment. Properly compounded products will meet the requirements satisfactorily and there should be practically no tendency for them to cause corrosion or pitting of balls, rollers or raceways unless op-

Fig. 3—The gearing on this lathe is exposed to dust, dirt, and metallic cuttings.

An oil of sufficient fluidity to permit of ready application, and yet with enough body to stick and maintain a protective lubricating film on the teeth must be used. Certain of the gear shaft bearings are served by pin-type grease cups as indicated by the arrows.



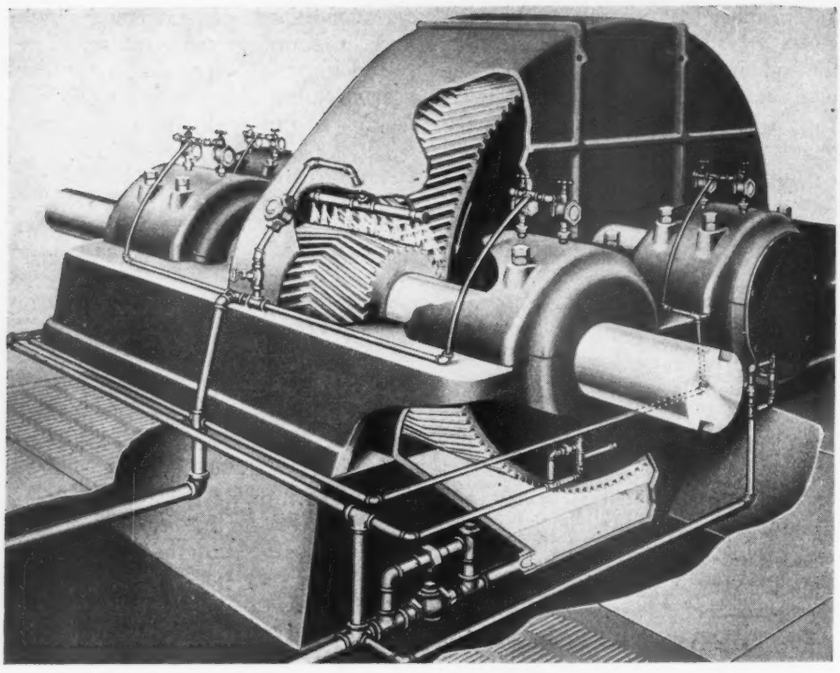


Fig. 4—This set of herringbone gears is lubricated by a circulating pressure system.

The nature of the housing and means of circulating the oil render effective lubrication possible, insuring against abnormal wear of the gear teeth and shaft bearings. The oil is delivered to the teeth as they go into mesh.

erating conditions are extremely abnormal.

As to frequency of lubrication it may be stated that, whatever the lubricant specified, a properly-designed ball or roller bearing will require replenishment of this product but once every three or four months, and oftentimes at less frequent intervals if the housing is capable of holding a relatively large volume of lubricant, and an effective seal is maintained to reduce leakage or contamination to a minimum.

Principles Underlying Lubrication of Gears

Lubrication of gears presents a different problem and may be said to involve a threefold purpose: the prevention of wear, the elimination of noise, and the reduction of power consumption. In many plants the gears of industrial machinery are neglected. They are oftentimes relatively large in contrast with the other wearing elements, and as in Fig. 2, may be massive. No wonder that their lubrication is neglected, especially where there is possibility of gear lubricant being thrown from unguarded elements as, for example, on certain types of metal presses.

Furthermore, many are prone to regard gear lubrication as of little consequence, on the assumption that the greater proportion of the motion involved is rolling. Sliding motion will always exist, however, and sliding motion imposes considerably more wear on the gear teeth than does rolling motion. In addition, as wear takes place sliding motion will supplant rolling motion in a constantly increasing degree. Irrespective of the type of motion, gear tooth friction will be reduced to a minimum if the lubricant has been properly prepared and is carefully applied. The result will be the reduction of noise, the elimination of vibration or chattering between the teeth and the prevention of abnormal wear in the average installation.

According to the type of service for which they are designed, gears may be built encased or exposed. As a rule this will depend upon the extent to which foreign or abrasive matter is present, or the requirements as to safety. Gears should always be guarded, but whether or not these guards are oil-tight will depend upon the importance attached to lubrication.

Oil-tight casings render bath lubrication possible and this in turn insures the utmost protection of the teeth, provided the oil is of sufficient body or viscosity to withstand the pressures to which the teeth will be subjected. In general an oil of from 100 to 200 sec. Saybolt viscosity at 210 deg. F. will be best for bath-lubricated gears.

On the other hand where gears are exposed, as in Fig. 3, a heavier product will generally be necessary, for the lubricating film must be capable of adhering tenaciously to the teeth, resisting temperature changes and the effects of speed and centrifugal force which tend to throw off the lubricant and leave the surfaces exposed to metal-to-metal contact.

The lubricant on the average gear installation performs an especially important function in that it serves to eliminate noise and vibration. The reduction of vibration is regarded by many as being just as essential as the maintenance of a lubricating film of proper thickness.

Herringbone gear trains, Fig. 4, generally run in a bath of lubricant or are equipped for pressure lubrication. In such installations it is frequently essential, or desirable, to use the same grade of lubricant on both gears and the adjacent bearings. For this purpose an oil of from 300 to 750 sec. Saybolt at 100 deg. F. should serve the purpose, depending on the severity of service, the size of the gears, and the design of the machine. Where such gears are bath-lubricated, however, it may often be more satisfactory to use a heavier-bodied product, with a viscosity range of from 100 to 200 sec. Saybolt at 210 deg. F. according to the size of the installation.

The lubrication requirements of bevel or angular gears differ but little from those of spur gears. In fact, the only difference in conditions will be in the relative amount of sliding and rolling motion. In general, the former will predominate, due to the greater difficulty that is frequently involved in the accurate cutting of teeth and alignment of the respective elements in assembly.

The lubricant should, therefore, be fairly heavy in order to meet these possible difficulties and to insure the maintenance of a sufficient film to take up any shocks involved, as well as to resist the wiping effects of such sliding motion as may occur during operation.

In turn, the lubrication of annular gears involves much the same requirements as encountered with spur gears. In fact, where they operate exposed, practically the same grades of straight mineral, semi-fluid lubricants as would be required on exposed spur gears should be suitable. It is interesting to note, however, that the effect of centrifugal force on an annular gear, is just the reverse of

that on a gear with externally cut teeth. As a result, there will not be the same tendency for the lubricant to be thrown off, except as it is taken up by the spur teeth of the driving pinion. Where such installations are designed for bath lubrication, a lighter, more fluid oil, selected with due regard for the pressures and size of the teeth, can be used to good advantage, thereby reducing the possibility of development of abnormal internal friction within the lubricant itself.

In the case of worm gear installations the manner of housing renders bath or splash lubrication generally possible. Operating and constructional conditions, however, will require a relatively wide variation in the viscosity of the lubricant to be used. For example, in certain instances a gear lubricant of approximately the viscosity of a straight mineral cylinder oil should be selected. In other cases a machine oil of from 300 to 750 sec. Saybolt viscosity at 100 deg. F. will suffice.

In all worm gear installations the level of the oil is of decided importance. The development of "drag" or excessive internal friction may become a decided factor in the matter of power consumption. As a result, the oil should be carried at such a height as just to insure suitable immersion of the teeth of the lower element. It is not advisable to submerge it too deeply.

The distribution of the lubricant from the teeth of the gear to the respective shaft and thrust bearings is usually provided for, although these can be lubricated externally if desired. Where the worm is located below the wheel or gear, the oil level should usually be carried at the center line of the worm shaft. Where the worm is above the gear, the gear teeth will carry less lubricant to the worm than the worm would to the gear teeth. As a result, a heavier, more adhesive lubricant may often be necessary, or the level of the lubricant may have to be raised in the gear case to a certain extent, dependent on the speed of operation.

Regardless of the type of gear, however, gear lubricants should in general possess certain definite properties if they are to function as intended.

The viscosity should be commensurate with the method of lubrication and the amount of heat that may prevail in operation.

Adhesive qualities should be sufficient so that where the lubricant must be used under exposed or semi-enclosed conditions, the lubricating film will remain on the teeth and resist the tendency of centrifugal force to throw it off.

There should be little tendency to congeal, harden, crack or turn brittle when the lubricant is exposed to low temperatures; nor should such a lubricant carbonize when used under high temperatures, as in cement mills, for example.

Straight mineral lubricants will in general be found most capable of meeting these requirements on power transmission equipment, although blended or compounded products may frequently be offered for the purpose. In the case of the latter it is important to see that they contain no non-lubricating fillers. The purpose of using the latter would be to increase the viscosity or plasticity of the resultant product. On the other hand, they will frequently reduce the lubricating value. In addition, lubricants with such contents will lack to an appreciable degree the adhesive characteristics that may so often be decidedly essential. As a result, when they are used under exposed conditions, on high-speed gears subjected, perhaps, to the detrimental effect of water, acids or alkalies, the teeth may suffer materially due to the inability of these lubricants to resist the effect of centrifugal force, the washing action of water, or the corrosive effects of certain chemicals.

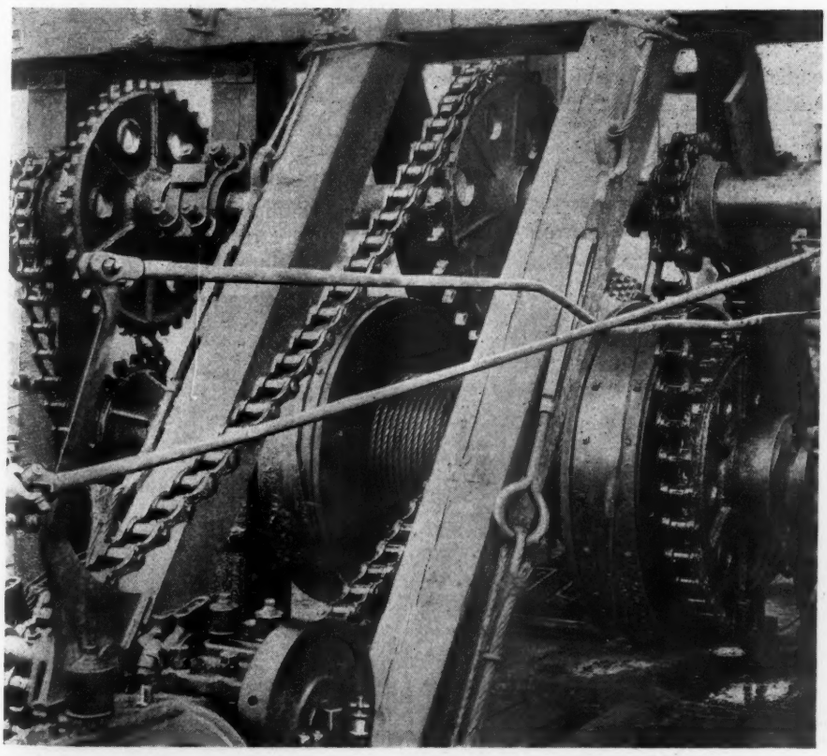


Fig. 5—The roller chain when exposed also presents a lubrication problem.
Effective lubrication is obtained by removing the chain periodically and immersing it in a bath of relatively heavy gear lubricant. The resultant film will prevent the entry of foreign matter.

Essential Requirements in Lubrication of Chain Drives

Chain drives for power transmission and speed reduction employ either the roller-type chain, Fig. 5, or the so-called silent chain, as shown in Fig. 6.

Cleanliness of operation is usually an essential feature of such installations, especially on overhead systems where the chains and sprockets are often exposed. Therefore, less lubricant will be needed, inasmuch as little or none of it will normally be thrown off by centrifugal force, even under higher speeds of operation.

Speed involves the frequency of shock due to engagement of the chain links with the gear or sprocket teeth. Whether such shocks will be detrimental to lubrication will depend upon the load and constancy of operation. It is natural to expect that the rapid repetition of such shocks upon the bearing points of the chain will tend to force or squeeze the lubricating film out from between the wearing surfaces.

It is impracticable to compensate

for this condition by increasing the viscosity of the lubricant to any great extent, as is often done on heavily-loaded bearings, for the penetrative ability of the lubricant would thereby be markedly decreased, especially in view of the small clearances involved.

It is evident that the lubricant must have sufficient fluidity to penetrate thoroughly the entire link, whether pins and bushings, rollers or rocker joints are involved.

On the other hand, to prevent external wear of the sprocket teeth and chain, a relatively heavy, adhesive lubricant should be used which will both resist any possible effects of centrifugal force, and stick to the wearing surfaces. Such a lubricant, being regarded as semi-solid, is naturally too viscous to serve the internal bearings. Hence, we must compromise and select a lubricant of sufficient viscosity to meet one purpose, with the retention of as much adhesion as possible.

Certain steam cylinder oils, or petroleum residuums, have been proven to be the best bases for such a lubricant. They can, when necessary, be blended to the desired viscosity with lighter, straight mineral products, dependent upon the experience of the operator.

Bending or articulation of a driving chain imposes wear not only on the link pin bearings, but also at the points of contact between the chain and the gear or sprocket. This is often regarded as the chief cause of external wear on both, even though correct chain design works toward the elimination of this tendency as far as possible, confining any necessary rubbing or rolling to the joints of the chain. As a result, a suitable lubricant should be capable of effectively serving both internal and external wearing points, at all times.

The duty imposed upon any such lubricant will, of course, become all the greater when chains must be operated in the presence of dust, dirt, water, or chemical fumes. In such cases it must serve as a lubricant, and as a protective agent for the bearing surfaces. Foreign matter such as grit, dust, acids, and moisture will tend to promote wear and corrosion to a marked extent.

Grit and dust are extremely penetrative; therefore, they will always tend to work into clearance spaces and immediately increase the wear. As a result, unless the lubricant is of the proper viscosity and base, it will often become incorporated with such foreign matter and develop an abrasive tendency that may ultimately lead to marked increase in power consumption and repair costs.

It has already been stated that a chain lubricant must penetrate to the rollers, rockers or sliding surfaces of the links, for it is evident that it will do no good to apply a lubricant to the surface of a chain if it has not the penetrative ability to reach the clearance between the wearing surfaces by virtue of its viscosity. Oftentimes too little attention is given to roller chains, due to their seemingly rough construction. This is shown by the use of waste oils that are carelessly applied at intermittent intervals.

Any such lubricant should be brushed uniformly over the wearing surfaces while they are operating slowly. Heating of heavier products will often be advisable in order to facilitate the spreading of a thin, even coating, and to insure proper penetration.

Silent chains, in turn, may operate exposed, or in an oil-tight casing. The speed of operation is oftentimes regarded as a guide as to the advisability of using a casing. In service where dust, grit, or other foreign matter is present a casing is always advisable whatever the speed; otherwise excessive contamination of the lubricant may occur. Any chain that operates in a dust-proof, oil-tight casing and is equipped with some form of automatic lubricator will require the least attention and operate most efficiently.

Splash lubrication, using a disc or collar attached to one side of the main shaft, is one way of bringing this about. As the wheel rotates the disc dips into the oil in the base and throws it to the top of the casing which is built in the shape of a wedge. In consequence, there is a continuous dripping of oil upon the chain. In casings of this type, the oil level is below the chain, the disc alone dipping into the oil.

There are other types of casings that depend upon bath lubrication. In these the oil level should be somewhat above the lowest part of the chain, for the latter acts as its own oil distributor. Where high-speed chains are involved, the casings are often equipped with an oil pump. Pressure lubrication is thereby obtained, the oil being sprayed continuously upon the chain links.

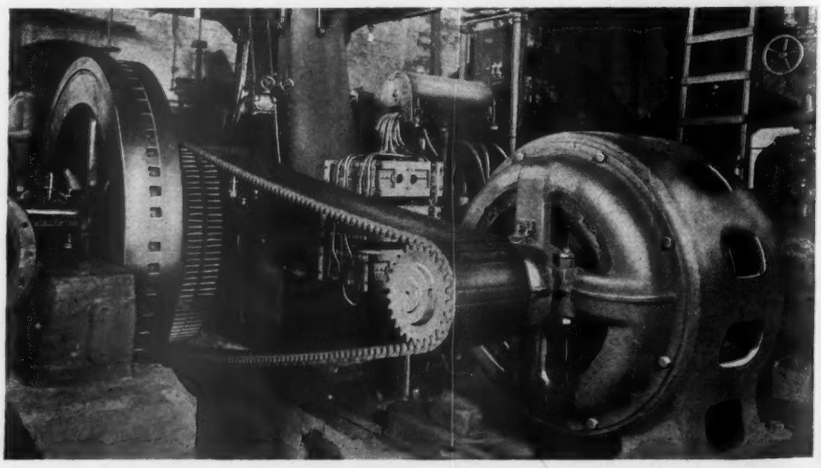
Where a silent chain is exposed or uncased, however, the lubricant must be applied either by brushing over the driving surface, or by removal of the entire chain for treatment, such as immersion in the lubricant.

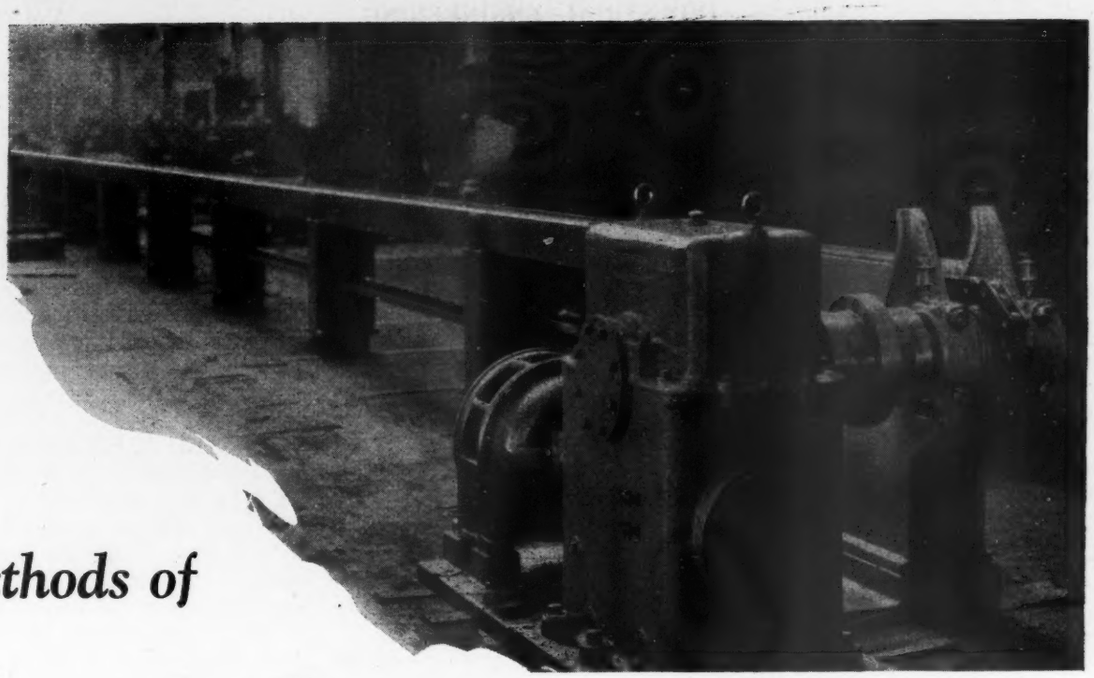
The necessary frequency of any such treatment will, of course, depend upon the type of chain, the speed, and the possibility of the lubricant becoming contaminated. Inasmuch as clearances in silent chains are usually very small, it is generally advisable to use a relatively fluid straight mineral oil for such treatment. When chains are encased, if they are to be bath-lubricated, a machine oil having a viscosity of from 500 to 700 sec. Saybolt at 100 deg. F. will be suitable. Where exposed, however, or encased but not immersed in oil, a heavier lubricant such as a mineral cylinder oil or light gear lubricant should be used.

Greases are also suitable for use on exposed chains, especially where there is sufficient clearance to enable proper penetration and retention of the lubricating film.

Fig. 6—An exposed silent chain drive requires care in the application of lubricant.

A light grease is frequently preferred so that it may be brushed onto the under side of the links from whence it works its way into the clearance spaces of the connecting elements.





Worm-gear drive on a 10,000-lb. drawbench. Shock and impact characteristics of the load impose severe operating conditions on this worm-gear unit.

Methods of handling

Shock or Pulsating Loads

IN THE design of any power transmission system, either electrical or mechanical, shock loads constitute a very troublesome but important factor that must be given careful consideration. Whether shock is represented by the surges on a transmission line, the impulses of a reciprocating pump, the impact of rolling mill service, or the effect of inertia caused by the sudden starting and stopping of equipment, due allowance must be made for it, if reliability of service and freedom from high operating and maintenance costs are to be obtained.

In the mechanical transmission of power, shocks may take the form of large and sudden increases in load, at regular or irregular intervals, or they may be represented as smaller variations in load that occur rythmically, or on a definite time cycle. The term pulsating is frequently applied to the latter type of load.

When the load on any piece of equipment is comparatively uniform and constant the problems involved in designing the machine and laying out the drive are usually relatively simple. Stresses can be calculated with reasonable accuracy and with our present knowledge of the strength of materials it is not a difficult matter to design the various elements so as to allow as large a factor of safety as may be desired or dictated by good practice. When shock or pulsating loads are encountered, however, more complicated problems are presented. It is not always an easy matter to determine the magnitude of the shocks or impulses that the equipment will have to stand. Consequently, there is considerable room for the exercise of good judgment, based on previous experience in solving similar problems, in deciding how shocks may best be absorbed and how much excess capacity must be allowed in the equipment that is selected to do the work.

From the standpoint of the power transmission engineer the presence of a shock or pulsating load should indicate the necessity for a careful study of the operating requirements and conditions peculiar to each installation. It must also be borne in mind that in the case of machines whose power consumption fluctuates suddenly and widely the drive connection between the motor and the machine shaft should be considered with reference to the maximum load that is to be placed on it at any time, and not upon the average load to be transmitted.

On the other hand, when selecting a motor for a given drive, advantage should be taken of the fact that motors will stand considerable overloads for short periods of time. This characteristic will generally permit the selection of smaller motors than are usually applied. The usual tendency is to select a motor to fit the maximum demand placed on the machine, rather than one whose rating more nearly corresponds to the average load.

Successful transmission of power to machines that impose a shock load is not confined to any one type of drive. Direct connection of motor and machine through a flexible coupling, and belts, chains, and speed reducers have all been used with success when the application was properly worked out.

The following examples will serve to show how some interesting problems were solved in the transmission

of power when shock or pulsating loads were an important factor to be considered, and other operating conditions such as the necessity for maintaining short center distances and so on imposed limitations that made the problems more difficult to solve.

F. E. BARDROF, *The Cleveland Worm and Gear Co., Cleveland, Ohio.*—In the older plants devoted to the manufacture of seamless tubing products, all drawing benches were driven from one source, by means of a shaft that extended the entire depth of the plant, and perpendicular to the benches. As production increased and additional benches were added, the drive shaft was extended by coupling to the original shafting until the limits of room and the driving unit had been reached.

The driving unit originally consisted of a steam engine driving the main shaft through a train of gears, or by means of belts and lineshafting if two parallel main drive shafts were employed. In this system of group driving a large main motor eventually replaced the engine as a source of power.

With this change, however, the usual troubles existed as in the earlier type of drive. The main shaft furnished the power for each individual bench, necessitating continual service for one or all benches whether drawing tubing or not. The driving unit of the group-drive system had to carry the friction losses of the equipment under any schedule of production, as well as the enormous stresses from shock when under full production schedule.

One large manufacturer of seamless tubing, after installing the unit-drive system found it so satisfactory that additional orders have been placed for duplicate equipment. Each drawing bench, as shown in the illustration, on page 477, is a complete unit consisting of the bench and the drive equipment, which is located at the foot of the bench.

A 25-hp., 720-r.p.m. motor is used to drive the chain and carriage through a size 600 AT Cleveland worm-gear reduction unit with a speed reduction of 22.5:1. Connection to the bench drive shaft from the speed-reducing unit is made by means of a flexible coupling. With this type of drive, the principal advantages are compactness, flexibility, and low operating cost. It is evident, however, that this service is very severe on account of the shocks and impacts which it imposes on the drive.

G. D. HERTZLER, *De Laval Steam Turbine Co., Trenton, N. J.*—In order to avoid a high-peak load due to the shock loads from the operation of grinding equipment, the pebble grinders in a flour mill are operated at night when the remainder of the plant is shut down.

Each pebble grinder is charged with its batch of material, and when a revolution counter indicates that it has run the exact number of revolutions to produce the proper consistency of the product, the grinder is shut down.

With the belt drive formerly used it was necessary to operate the 50-hp. motor until the last grinder was shut down, so that the motor was running a great part of the time with very light load and a correspondingly lower efficiency.

In operation these grinders impose a shock load of considerable magnitude on the driving equipment. After De Laval worm-reduction units and individual motor drive had been installed on each grinder, it was found that the required number of revolutions were reached more quickly due to the absence of belt slippage and also that there was a considerable saving of power. The grind is now completed in three and one-half nights instead of five, and four mills now do the work that formerly required six. Only one man is needed instead of two, and there is less maintenance. In addition, operating costs have been reduced one-third.

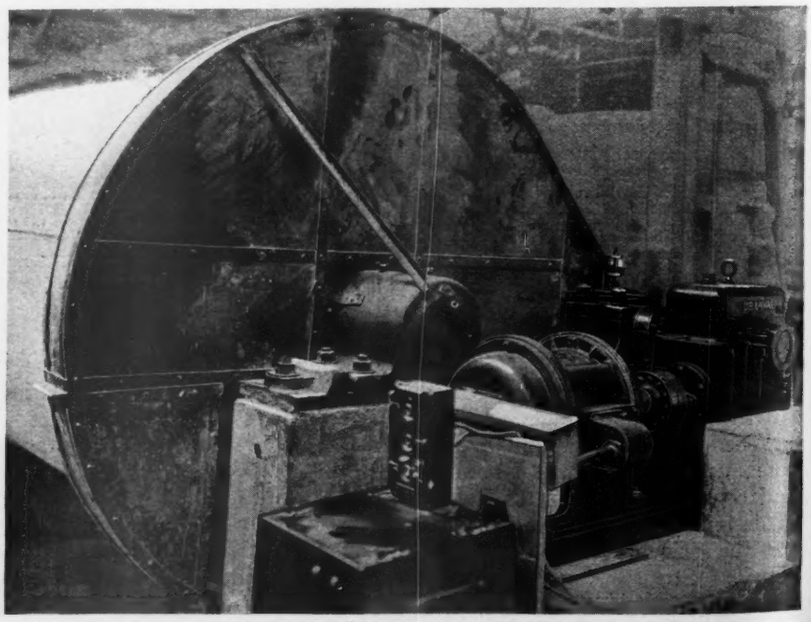
Other incidental advantages have been the elimination of oil drips from shafting and leather lint and dressing from the belts, which helps to keep the plant scrupulously clean; consequently spoilage is reduced. There is also greater uniformity of product.

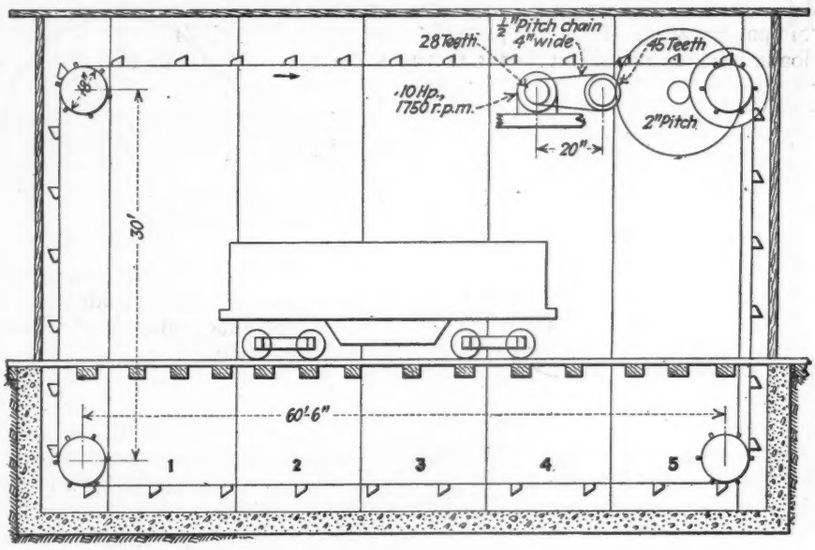
DONALD A. HAMPSON, *Plant Superintendent, Morgans & Wilcox Mfg. Co., Middletown, N. Y.*—Solid steel disks on which the outlines of teeth were faintly discernible represented the remains of gears that been the driver and driven members of the first reduction in the train that drove the conveyor of a coal-handling system. These gears of five pitch, one having 30 teeth and the other 50, had been in service for only three months when they were stripped while several cars of coal were being unloaded. In order to meet the emergency, blanks for 10-in. gears were obtained, milled and delivered the day following receipt of the blanks. Three months later these gears failed.

Inasmuch as the original gears had a 2-in. face, we provided new gears with a 3-in. face so as to give increased wearing surface. Checking up on the load while waiting for these blanks to arrive, it was found that there was ample wearing surface even on the original gears. However, some three months later this set of

One of six pebble grinders that were formerly driven from line shafting and belts by a 50-hp. motor.

Severe service is encountered in this type of equipment due to the pulsating character of the load caused by the piling and rolling action of the pebbles with the charge.





The drive connection between the motor and the main shaft of this coal-handling system is subjected to heavy shock loads.

After three sets of gears had failed following about three months' service each, a Morse chain was installed in place of them and has been in service for 13 years.

gears failed also, causing a shutdown.

As shown in the illustration, the coal is dumped underneath the track into a pocket which tapers off to a 2-ft. trough along which the conveyor system is driven by means of a 10-hp., 60-cycle, 1,750-r.p.m. repulsion motor through gear trains to the bucket sprocket wheels.

The buckets and chains traverse the bottom of the steel-lined pit and ascend 30 ft. to the upper level where the coal is delivered to the bin specified. The bins are indicated in the accompanying illustration by perpendicular lines, and numbered from left to right.

The gears in the first reduction necessarily operated at high speed and were pulling a severe pulsating load. In addition, they were frequently subjected to heavy shocks caused by choking of the conveyor with coal as the cars were dumped.

After three similar failures, something had to be done; so after a study of the problem we decided to install a silent chain drive. Accordingly, a ½-in. pitch Morse chain 4 in. wide with two guide links and two sprockets, one having 28 and the other 45 teeth were obtained and installed as shown in the illustration on this page.

A recent inspection of this drive after 13 yr. of service leads us to believe that it is in condition to render as many more years of reliable service under the same operating conditions.

These conditions are really very severe. In addition to the hard service imposed by the character of the load the drive is located close to the roof where it receives very little attention and is exposed to a large amount of coal dust, without any protection.

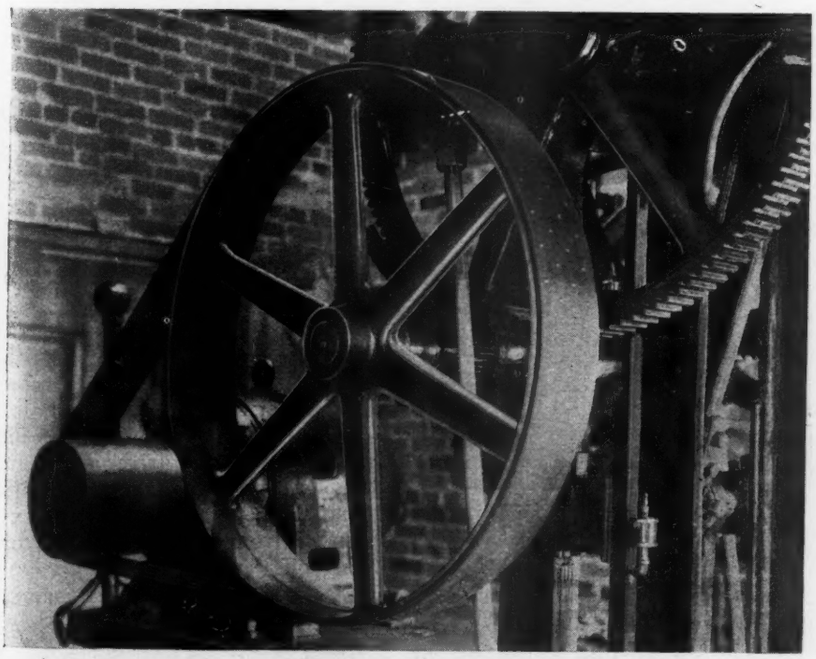
J. L. De RABOT, *Consulting Engineer, Alexander Brothers, Inc., Philadelphia, Pa.*—A drive that gave considerable trouble was encountered on a deep-well pump installation where the shock of the pulsating load from the reciprocating action of the plungers was transmitted to the drive connection between the motor and the first reduction element of the pump.

Due to the space available for the equipment, the distance between centers of the first reduction was unusually small. A 10-hp., 860-r.p.m. motor having a 10-in. pulley, drives a 36-in. pulley on the pump at a center distance of only 30 in.; so the very small arc of contact on the motor pulley is obvious.

Under identical conditions of operation, gears had been used in this first reduction element, but after several failures due to the nature of the load and perhaps careless operation, they were replaced with a chain drive which ultimately fared no better than the gear installation.

On account of the short center distance of the drive as it was installed, little consideration was given to the use of belting, because in addition to the small arc of contact on the motor pulley, the belt would have to pull from the top side. However, under the assumption that the pulsating load was responsible for the failures of the previous drives, in that the connection was unable to absorb the shocks, the 5-in. Tentacular belt shown in the illustration at the left was recommended and installed.

Despite the unusually severe service that this installation imposes no trouble has been experienced from excessive slip or wear. The equipment is available for full capacity operation at any time.



The belt driving this deep-well pump carries a pulsating load while operating on short center distance.

Gears and chains had been used previously on this 30-in. pulley center drive, but failed to stand up. This is a tentacular belt.

R. C. MOORE, *Warren Belting Co., Worcester, Mass.*—Considerable difficulty was experienced in keeping a Curtis compressor at the Syracuse plant of the Dunning & Boschert Press Co. running, due to frequent belt failures.

Following a period of exasperating delays, the management requested us to make an analysis of the problem and submit our recommendations in order to arrive at some conclusion as to whether the compressor or the drive should be replaced because they were obliged to keep three belts on hand all the time. One belt would break and while it was being repaired, a second belt would sometimes break necessitating the use of the third reserve belt. As many as four belts were replaced in one year.

Knowing the type of installation and the rapidly changing loads to which any belt drive here would be subjected, our recommendations were for an 8-in. Wabeco double belt which was installed May 5, 1924. Since that time, it has been in constant service without layoff except at night and is still in good condition.

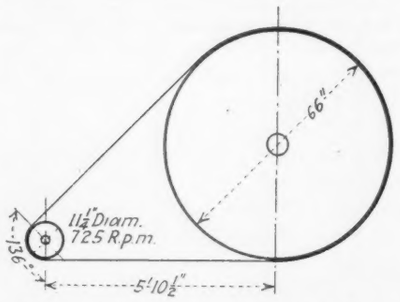
J. EDGAR RHOADS, *J. E. Rhoads & Sons, Philadelphia, Pa.*—One of the most severe shock loads that we have had to handle was encountered on the drive for a three-stage compressor in which the pressure was built up from a low figure to over 2,000 lb. per sq.in. in a very short time.

The drive consists of a 40-hp., 725-r.p.m. motor with an 11¼-in. pulley driving to a 66-in. pulley on the compressor with an 11-in. leather belt through a center distance of 70½ in. The speed of the compressor was, therefore, approximately 128 r.p.m.

An idler was formerly used on this drive to increase the arc of contact on the motor pulley, but a 3 per cent slip persisted when operating under the heaviest pressure. This drive was considered an extremely difficult one for this reason. Because of this condition the compressor was never able to attain its rated capacity. The pulsating nature of the load with what was thought to be the best belt in use prevented a reduction in slip which restricted the maximum output.

On the basis of service requirements for this type of drive a heavy double Tannate belt 11 in. wide was installed and run without employing an idler.

Even with the reduced arc of contact this belt is running with approximately 1 per cent slip, and the compressor is operating at its full rated capacity under maximum pressure in less time than was previously found possible. As shown in the illustration, the arc of contact is only 136 deg.



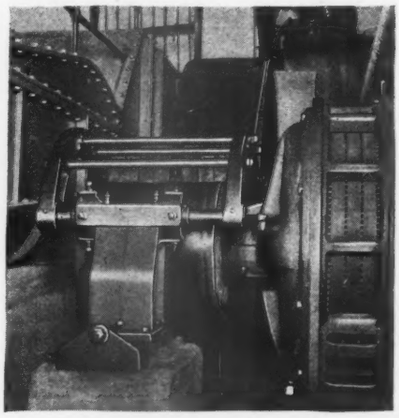
The arc of contact on the small pulley of this compressor drive is 136 deg.

Practically no attention has been given this belt which has been in service for many months, but repeated tests on it have confirmed the low percentage of slip.

STANLEY HASTE, *The Bird Machine Co., South Walpole, Mass.*—Drive equipment for the operation of breaker beaters must be of a substantial nature to withstand the shocks and variations in load to which they are usually subjected.

In a jute plant, such a drive having a 100-hp. motor on it contributed its share of interruptions to production by belt slippage and consequent burning that necessitated frequent renewals of the belts.

Lack of space around the machines prevented the adoption of any other type of drive and the width of the pulleys used restricted the use of belting material other than leather. Short center distance between the pulleys was also a factor for the continuance of belt drive; so in finding a way out, it was decided to use an idler.



The drive on this breaker beater is subjected to severe shocks and variations in load.

Excessive belt slippage and other trouble led to the installation of a Pulmax drive, which has eliminated the former operating troubles.

A Pulmax unit was installed as shown in the illustration at the bottom of the preceding column. A second-hand belt was put on the drive and after years of service is still in good condition.

The difficulties encountered prior to its installation have been entirely eliminated, for with sufficient capacity in the motor and belt for the maximum load in the beater, there is maximum contact area on the motor pulley to counteract any shocks transmitted by the charge.

With this arrangement instead of the shocks and load variations being absorbed by the belt, through slippage, they are now spread over and smoothed out by every element of the drive, including the distribution system.

Eliminating Belt Slippage on Coal Breaker Drive

BELT slippage is not only objectionable from an operating standpoint, but when severe it is injurious to the belt. In one instance that came to my attention, a good deal of trouble was experienced with a belt drive on a coal breaker. The 500-hp., 560-r.p.m. motor that drives this breaker has to start up under nearly full load. As a result, the belt frequently slipped off during the starting period, causing considerable annoyance and delay in production.

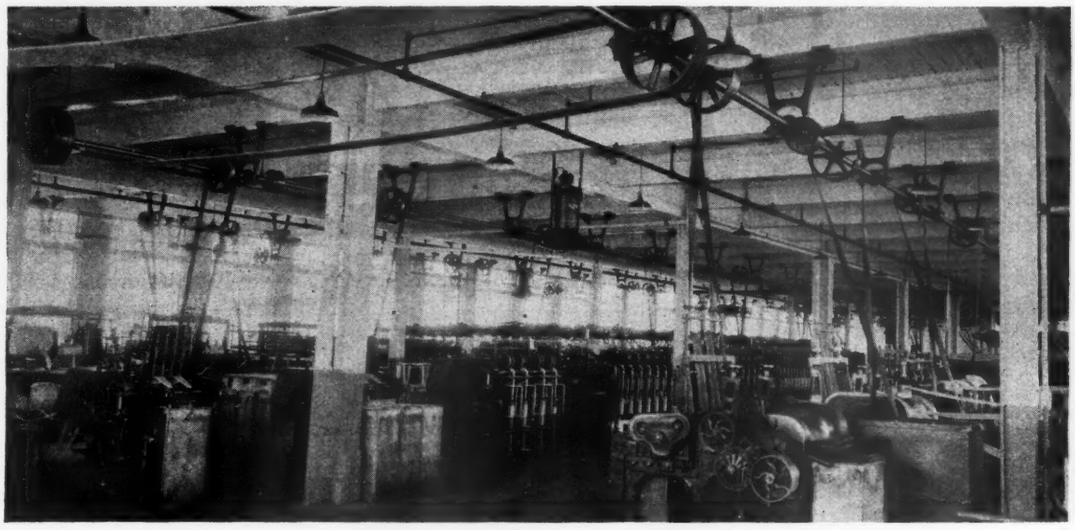
The motor is started from a central control room and time was naturally wasted in notifying the operator to stop the motor, when the belt came off. Even when the belt did not run off there was enough slippage to create a very undesirable operating condition.

Various methods of holding the belt in place were tried, but none of them was successful. Eventually one of our engineers was called into consultation and recommended the use of an American, cork-insert, split steel pulley. This pulley is a special, heavy-duty type 44.5 in. in diameter and 38 in. wide.

A 9-ply endless rubber belt 36 in. wide is used on the drive, and since the pulley was installed several years ago no further trouble has been experienced from the belt slipping or coming off the pulley.

D. W. PEDRICK.

The American Pulley Co., Philadelphia, Pa.



A view of one department in a Maine textile mill that contains about 1 mile of lineshaft supported by SKF self-aligning, ball-bearing hangers.

Bearing Troubles

How they have been solved

FOR many years the ordinary or sleeve type of bearing was used exclusively in all kinds of machines, and served its purpose well. Fifty years ago, say, the demands made on bearings were much less severe than they are today. Loads were in general less heavy and speeds much lower. Again, power losses through friction were not given the careful consideration they receive today. In short, the disadvantages of sleeve bearings were regarded as inevitable.

The development of modern high-speed and high-capacity production and power transmission equipment brought new requirements and new standards of bearing performance. There came likewise a clearer realization of the exceedingly important part played by bearings in the transmission and utilization of mechanical power. Various designs of anti-friction bearings were accordingly brought out in response to the obvious need for a bearing that possessed all of the good qualities of sleeve bearings and as few of their disadvantages as possible.

Out of the vast amount of research and development work that has been done on anti-friction bearings there have come two general types—the ball and the roller bearing.

Coincident with the development and application of anti-friction bearings, a good deal has been done to improve the sleeve bearing. Much of this work has been along the line of developing better bearing alloys and improving the method of lubrication, although one large manufacturer has designed a so-called sealed sleeve bearing for use on motors that has been very successful.

Much has been claimed for anti-friction bearings and in many installations their performance has justified these claims. Assuming that they have been properly applied, anti-friction bearings can usually be counted upon to give trouble-free service. Application of a suitable lubricant a few times a year is about the only attention required, whereas most sleeve bearings have to be lubricated weekly or oftener. Generally a saving in power can be made by the use of anti-friction bearings. One of the decided advantages over sleeve bearings is the fact that the starting friction is much less than that of the other type. This means that less power is required to start heavy loads and bring them up to operating speed. At usual operating speeds the running friction of good sleeve bearings is, however, much nearer to that of the anti-friction type than is sometimes realized.

Anti-friction bearings have solved many difficult problems and have demonstrated their value extensively.

Operating men are confronted with the problem of determining just where these fields lie in their plants. Using as a basis of comparison the average performance of sleeve bearings, such questions as, Under what conditions will the savings that anti-friction bearings can make justify their use? What part have they played in solving operating problems? What operating advantages do they offer? and so on, are interesting and important.

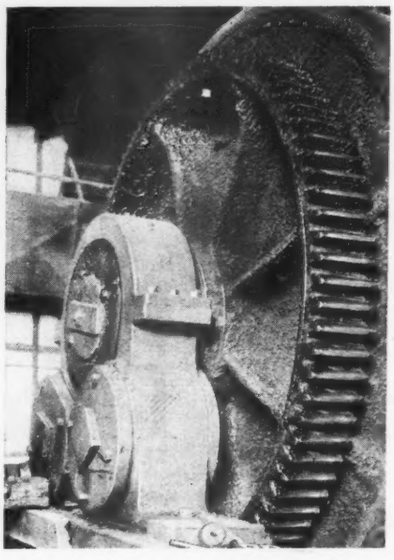
To these questions general answers based on the results obtained in service are given in the following pages.

A. K. WEST, *The Timken Roller Bearing Co., Canton, Ohio.*—An application of anti-friction bearings that possesses considerable interest, not only because of the operating improvements effected but because of the mechanical difficulties overcome was made to the trunnions of a mill or tumbling barrel used to powder enamel. The mill consists of a barrel, or drum, about 8 ft. in diameter and about twice as long, which is driven by a 25-hp. motor from a lineshaft. When filled it forms a load of about 10,000 lb. on the trunnions. The conditions under which it works call for what amounts to 24 hr. operation, seven days a week, since each batch requires a 36-hr. run, and the batches succeed each other as fast as one can be taken out and the other put in.

Before going into the results obtained by the bearings, a description of the method of applying them may be of interest. There are four stub trunnion shafts, two at each end. Each shaft is mounted on two Timken bearings, arranged indirectly, that is, having the apex of the angles of taper in the center of the shaft between the cones. The cups are pressed into the opposite ends of a retaining ring, or sleeve, and are located by shoulders machined in the ring. At this point there is a slight difference in the arrangement on the two ends of the drum shaft. On the gear end, a collar is shrunk around the drum shaft on which there is a tongue, that engages a slot cut into the outer surface of the bearing retaining ring. The purpose of this guide collar, as it is called, is to locate the shaft with respect to the trunnion bearing assembly. On the other end of the drum shaft the guide collar is omitted.

Before tapered roller bearings were adopted on this machine, considerable bearing trouble was experienced, due principally to the load characteristics of the machine itself. In machines of this sort, there is always a tendency for the whole mass of material in the interior to climb part way up one side, and then fall to the bottom against the direction of rotation. The consequence is that a heavy fluctuating load is placed on the bearings, and unless they are designed to withstand it, it may cause trouble.

At first plain sleeve bearings were used in the trunnions, and the effect of the condition just described was that the bearings had to be renewed about every six months. The next thing tried was a straight roller bearing, built by the owners of the machine, and, although these were an improvement, a good deal of trouble was still experienced. The effect of the shifting load was such that ridges were soon worn in the lower surface of the outer bearing race, which caused uneven wear and other troubles with the rollers. A remedy which was adopted for this condition consisted in turning the bearings on the shaft periodically, so as to bring a fresh surface under the rollers at the point where the wear occurred. However, even this was not very satisfactory because of the delay and labor involved.



Close-up view of Timken-equipped trunnious on an enamel-pulverizing mill.
In machines of this type, the tendency is for the charge to climb part way up one side and fall to the bottom against the direction of rotation. A heavy fluctuating load is thus placed on the bearings, and greatly increases the severity of the service.

Timken bearings were installed well over a year ago and, in spite of the fact that the machine is operated continuously, there has never been any delay, or other trouble caused by the bearings. In addition, the friction load formed by the machine has been materially reduced, which has resulted in a saving in the power required to drive it. The actual amount of power saved is not known, because other equipment is driven from the same lineshaft, but it is estimated at between 15 and 20 per cent.

As an indication of the reduction in friction that has been effected, the following feature is illuminating. Before the machine was equipped with its present bearings it was necessary when starting it up loaded to rock it through an arc of about 90 deg. several times before applying the power. Now it can be started from a standstill when loaded, without putting any undue strain on either the motor or the power transmission equipment.

H. E. STAFFORD, *Electrical Engineer, Provincial Paper Mills, Ltd., Port Arthur, Ont., Can.*—In our power plant we generate over 2,000 boiler horsepower, mine run coal being fed to the boilers by mechanical stokers. The coal-handling equipment consists of a crusher, an elevator leg, and a belt conveyor driven by motors which were installed in 1923.

For some time, considerable trouble was experienced with the lubrication of the crusher motor, which was equipped with sleeve bearings and open endbells. As the crusher is belt driven, a considerable amount of coal dust was carried on the belt to the motor, although it was protected by a curtain.

In order to overcome the bearing troubles, new endbells were cast, with provision for mounting ball bearings in them. The endbell at the pulley end was blanked so that the motor is totally inclosed on that end, and the opposite endbell was provided with small openings for ventilation.

Before changing the motors to ball bearings, it was a common occurrence to change at least one bearing every two weeks, whereas since the change was made no more bearing troubles have occurred.

A. A. McGOWAN, *Marlin-Rockwell Corp. (Gurney Division) Jamestown, N. Y.*—In these days of high-speed equipment and of mass production, manufacturers are continually on the lookout for ways and means of improving their product. Ball-bearing applications are doing their part in helping the manufacture to get the utmost from his product, and in many cases at very little additional expense.

A typical example of this came up some time ago. A well-known manufacturer of high-grade, rubber-working machinery had just placed on the market a high-speed tuber that was not giving the results expected from it. The output was exceedingly low when compared with the power consumption.

The principle of operation of this machine is similar to that of the ordinary kitchen meat grinder. The hot, gummy stock to be cleaned or refined is fed into the machine, and forced through a strainer at the out-

put end. When used as a tuber, a die is used in place of the strainer and a continuous seamless rubber tube results.

A tremendous thrust load is built up by the stock screw in forcing this mass of gummy rubber through the strainer or the tubing die. In the original application, a large, marine thrust bearing was used. Bearing failures were frequent and while these machines were being repaired, production was stopped and a double loss ensued. Maintainance costs became a bone of contention.

Lubrication was still another problem. The heat that developed from the tremendous worm thrust would raise the temperature of the oil to the boiling point after a period of operation. This necessitated an elaborate cooling system for reducing the temperature of the lubricant. The babbitt bearing would wear and the stock screw would get out of alignment with respect to its shell. As the bearing wore, the oil seal became less effective and lubricant began leaking out of the housing into the stock.

One of our engineers was sent to study the application and to co-operate in the development of a new design. Loads were calculated, and as a result the proper type and size of bearings were selected and layouts made of the housing and of the mounting arrangement.

The manufacturer set up a sample machine and put it under test. A distinct saving in power was noted. With this new arrangement it was also found that the very small radial play of the ball bearing held the stock screw so accurately centered, that a more uniform product was obtained. Oil leakage was reduced to a minimum with a consequent improvement in the quality of the stock. This improvement in performance is reflected in the results obtained on three different types of tubers.

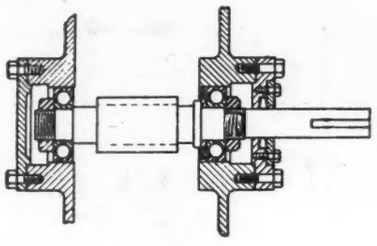
A 25-hp. tuber equipped with babbitted bearings throughout produced 1,500 lb. of stock per hour. An 85-hp. tuber equipped with a ball thrust bearing and babbitted radials produced 3,000 lb. of stock per hour. A 75-hp. tuber completely equipped with Gurney radial-thrust and radial bearings produced 6,000 lb. of stock per hour.

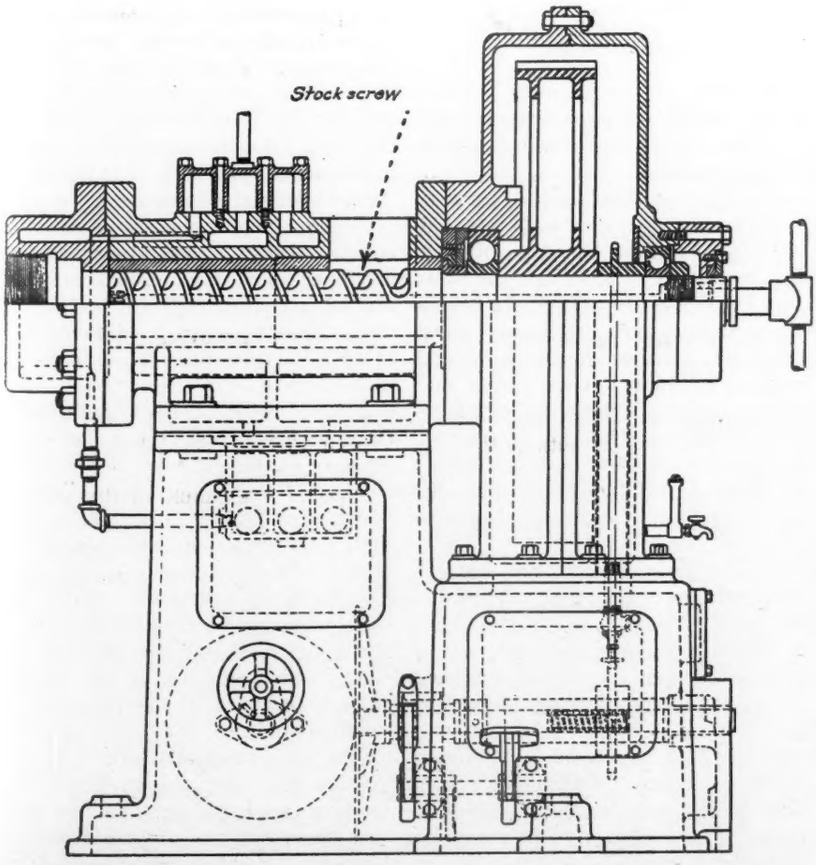
It is seen that there is a distinct difference in the relation of the horsepower transmitted to the pound output of the stock. The 75-hp. machine completely equipped with ball bearings produced double the output of the 85-hp. tuber and with less power, thus proving that the use of ball bearings converted the power lost in friction and boiling oil into useful work.

It is also of interest to know that a test was made of a peculiar stock that could not be put through the 75-hp. machine. The resistance was sufficient to stall the motor, but even under these extreme conditions there was no ill effect on either the machine proper or the ball bearings.

Cross-section view of rubber tubing machine equipped with ball bearings.

The view at the upper right shows the pinion drive shaft with its complement of Gurney ball bearings and the housing arrangements. In the lower view the bearing assembly is shown in connection with the stock screw, which builds up a thrust load when forcing the gummy stock through the tubing die.





H. R. REYNOLDS, *Chief Engineer, The Fafnir Bearing Co., New Britain, Conn.*—A large manufacturer of canvas belting and fabric brake lining found that his loom-drive pulleys cost him more to maintain than any other unit in his production line, because a force of tool makers was continually at work rebushing these pulleys, and repairing and replacing the clutch yoke brasses.

This loom drive was perhaps poorly designed in the first place; nevertheless a ball bearing replacement was the simplest way to cure the conditions and, strange as it seems, the work the ball bearings had to do here was almost nothing. This particular pulley application was a clutch of very simple design. It was simply a large-diameter pulley with a flange face, leather lined on one side with a clutch yoke and the necessary shifter arms on the other. To start the machine the shifter, through the yoke connection to the pulley, moved the

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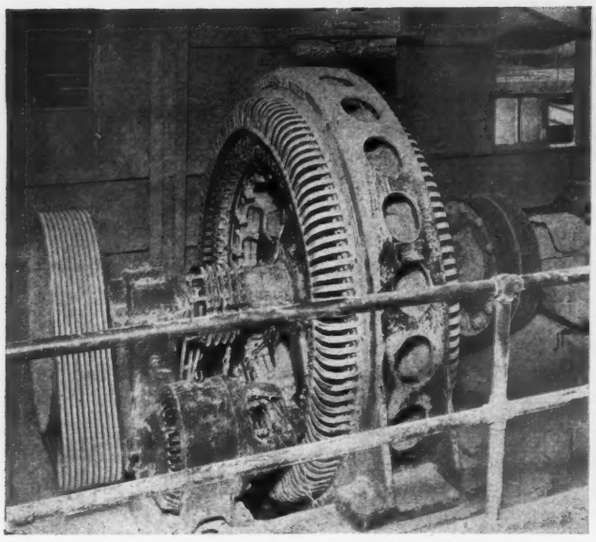
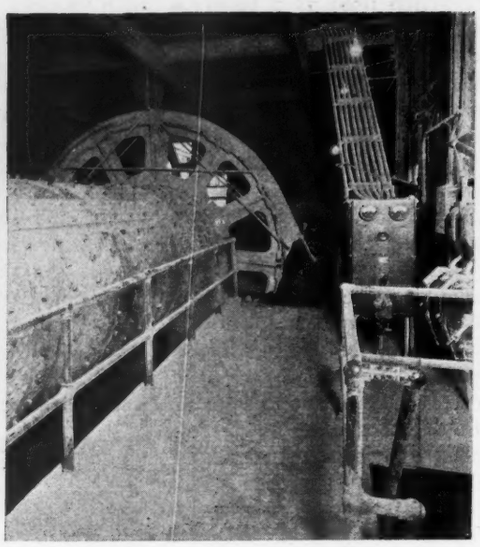




This 900-hp., 180-r.p.m., synchronous motor and the 8-ft.x35-ft. dry ballpeb mill for raw grinding, which it drives, are the largest units in the plant.

Methods of solving

Power Drive Problems

in a cement mill

By A. C. BROWN
Plant Manager
Kosmos Portland Cement Co.,
Kosmosdale, Ky.

FEW, if any, industries operate equipment under conditions worse than, or even nearly so bad as, those found in the modern cement plant. The severe operating conditions, such as dusty, abrasive atmosphere, high temperature, irregular and shock loads, heavy bearing pressures, and continuous operation, are particularly severe upon the equipment used to transmit power to the cement machinery or auxiliary equipment, such as conveyors, and so on, required in the production process. Luckily, most of the equipment is operated at comparatively low speeds which decreases to a certain extent the operating difficulties.

In the earlier days of the cement industry the short life of the equipment, bearings particularly, was considered as a necessary part and result of operation, and an allowance was made in production schedules for the expected interruptions. This necessitated the provision of extra equipment so that part of it could be down undergoing repairs, without interfering with production. Of course, some extra equipment must still be provided, but with the decrease in the amount of interruptions this extra equipment can be placed in regular production and so increase the output of the plant. Idle equipment, or machines waiting for maintenance, does not make cement and consequently is an extra expense.

The plant at Kosmosdale consists of a complete cement mill rated at 3,000 bbl. capacity per day with six kilns, two kilns 8½ x 125 ft. and four kilns 7 x 6 x 80 ft. and all the necessary grinding and pulverizing mills, conveyors, storage bins, sacking and handling machinery, coal storage and pulverizing equipment. The kilns operate continuously and the rest of the plant is on a 24-hr., six-day schedule, which gives about three times the operating service ordinarily found in industrial plants.

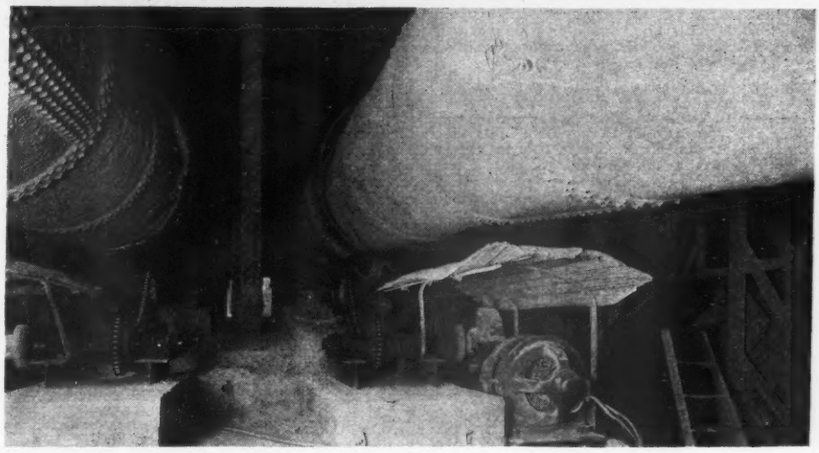
A quarry, coal mine, and fleet of river barges are operated in conjunction with the cement mill, but will not be included in this discussion. The product consists of Portland cement and masons' plaster manufactured by the dry process.

This plant has been in operation about 23 years. Maintenance consists largely of attention to and renewal of bearings, and other metallic surfaces in sliding or rolling contact, and the renewal of interior parts of the equipment exposed to the abrasive action of the materials in process. Maintenance of production equipment is a distinct and separate subject and will not be discussed here. This article will take up the operation and maintenance problems incidental to the drives on the equipment.

A large proportion of all bearing trouble results from inadequate or improper lubrication. The conditions around a cement mill are such as to make lubrication more difficult and at the same time much more necessary than in most industries.

When the plant was built plain bearings were installed, as was the practice in the industry at that time. Because of the heavy abrasive atmosphere surrounding these drives few of the bearings would last more than two or three months. As the bearings wore the difficulty of lubricating them increased because of the greater space between the bearing and the shaft, which admitted more abrasive material and made the retention of oil impossible.

The only practical method of preventing this wear was to supply lubricant to wash the abrasive dust away and prevent it from remaining in the bearing. Badly worn bearings re-



This shows the types of drives used on the driers and kilns.

In addition to the dust and heat, the drives on the driers (top view) are subjected to severe shock load, due to the rolling and sliding of the material. Both driers and kilns are driven by motors through worm gear reducers, chains and gears. The drives on this battery of driers are being rebuilt to incorporate an improved type of worm reducer, Timken bearings, and to simplify the drive. The canopy over the kiln drive (below) protects the motor and drive from the direct heat of the kiln and also from falling particles. Lubrication is a difficult problem because of the heat, dust, and heavy bearing pressures.

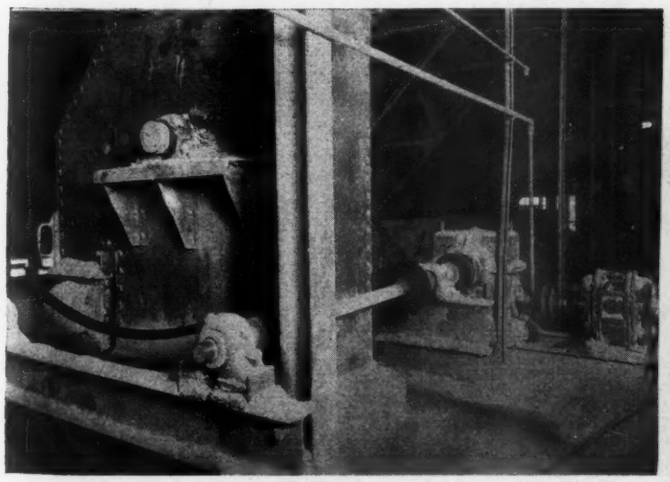
quired an excessive amount of lubricant to obtain even a short bearing life. Carelessness in application was responsible for a large wastage of lubricant. In addition, shafts became badly worn at the bearings and either had to be shifted so that another spot came in the bearings or be renewed.

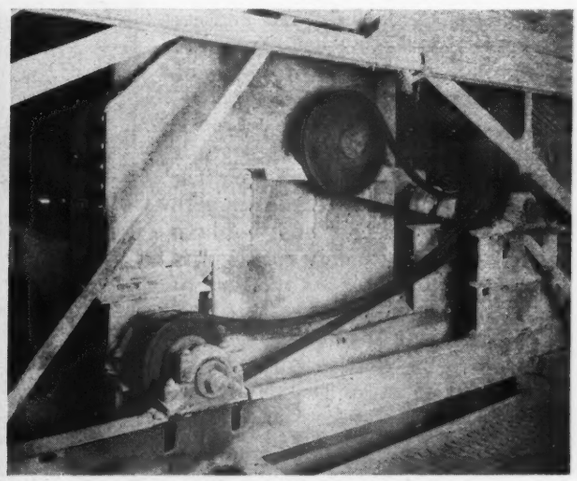
As an experiment a Dodge-Timken tapered roller bearing pillow-block was installed on a $3\frac{7}{16}$-in. shaft connected to a worm gear speed reducer driving an elevator head. Previously, an ordinary bearing seldom lasted three months on this work. Elevator head shafts are, as a rule, located in out-of-way places and are more or less neglected. This results in the shaft becoming out of line and causes excessive wear on chains and sprockets. This roller bearing has been operating for two years, without repairs of any kind. This is equivalent to between six to ten times the life of plain babbitt bearings under ordinary operating conditions.

After this bearing had been installed 12 months it was opened and thoroughly inspected for signs of wear. The results were so satisfactory that about 30 per cent of the bearings in the plant are now equipped with Timken tapered roller bearings or Fafnir ball bearings.

All elevator headshaft bearings and the bearings at the driving end of the screw conveyors have been replaced with tapered roller bearings. Plain bearings are still used at the discharge end of the screw conveyors where they do not receive such severe service as at the driving end.

Another place where roller bearings have been very effectively applied is on a $2\frac{15}{16}$-in. lineshaft, 70 ft. long driving mixing valves. This shaft is supported by nine Dodge-Timken pillow-block bearings and drives the valves through Diamond roller chains. These bearings have

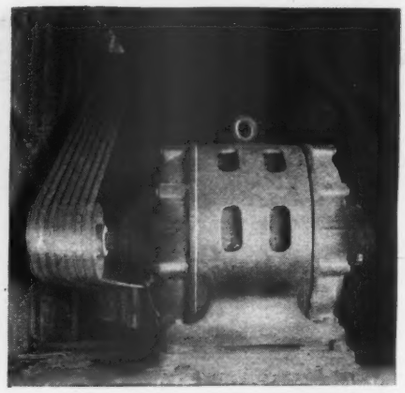




Two of the elevator and screw conveyor drives.

Each of the elevators and its screw conveyor must operate together; consequently the two are driven by a single motor through a Jones worm screw reducer which is connected through a flexible coupling to a $2\frac{15}{16}$-in. lineshaft mounted on Dodge-Timken pillow-blocks. The screw and elevator headshafts are connected by Diamond roller chains and are also mounted on Dodge-Timken roller bearings. Roller bearings have been in operation for more than a year in this kind of service, whereas the old, plain bearings seldom lasted three months.

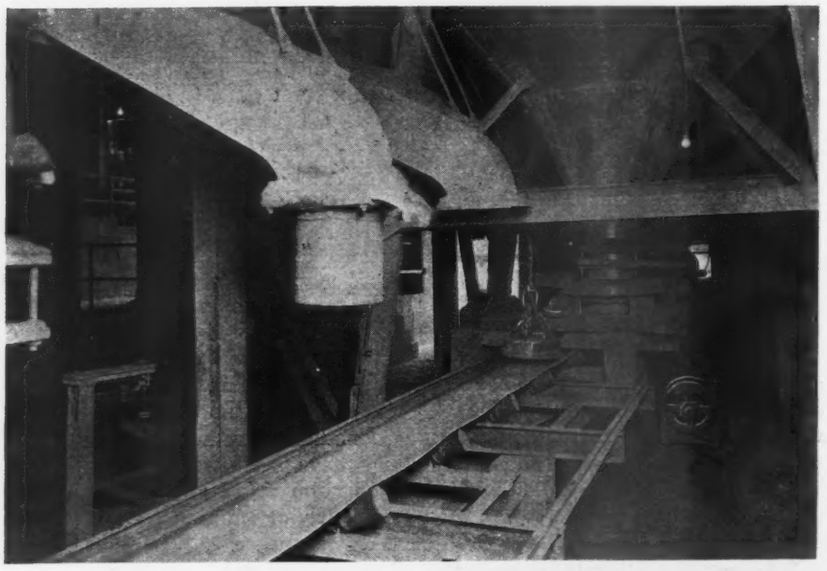
been operated without any trouble for the equivalent of four years of ordinary operation. Before the roller bearings were installed, plain bearings on this one shaft lasted only a few months; then the babbitt had to be renewed and fitted to the worn shaft or the shaft replaced. The plain bearings required about 10 gal. of oil per month, and received attention several times a day. Much of this oil was wasted, of course, because a plain bearing must be flooded to flush out the abrasive dust and, in addition, a considerable amount of oil is simply spilled or misses the bearing. The roller bearings and also the ball bearings are lubricated once a month with



An unusual drive on a cooler.
In spite of the intense heat, a Texrope drive has been in service on this cooler for almost a year without taking up.

Timken bearings provided with Alemite fittings for lubrication. Some of the conveyors have been changed over completely; altogether about 85 per cent of all the rollers have been changed to date. In addition, Dodge-Timken pillow-blocks have also replaced the plain bearings on the pulley shafts of the belt conveyors.

Motors and worm gear reducers are used on the belt conveyor drives.
Whenever a conveyor idler-roll sticks, it is replaced with a Link-Belt idler roll with Timken roller bearings fitted for Alemite lubrication. The driving pulley is also provided with tapered roller bearing pillow-blocks.



grease of light consistency through Alemite fittings.

The cost of the lubricant and its application under present conditions is approximately only 10 per cent of the former cost for the same line-shaft drive.

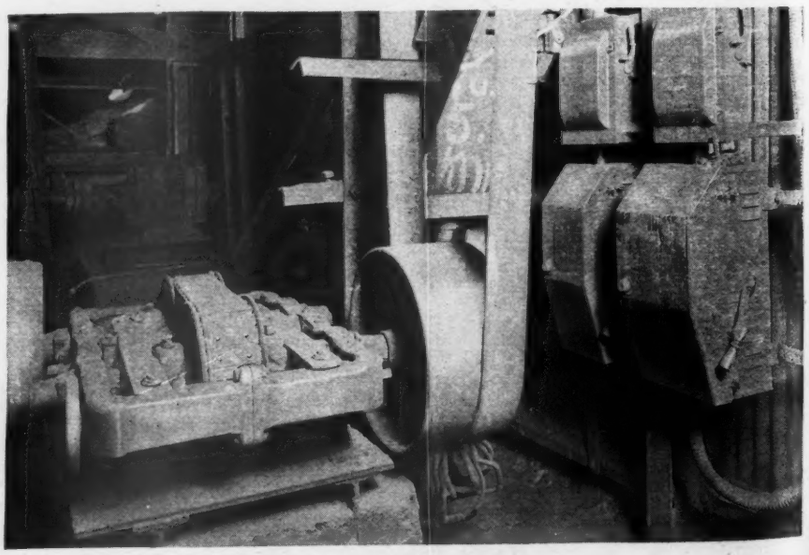
We are considering equipping our tube mills and a number of the other comparatively slow-speed drives with Timken bearings. So far it has been necessary to replace only one Timken bearing, and that was not the fault of the bearing.

The troughing and idler rolls on the belt conveyors were originally provided with plain bearings. Whenever a roll sticks and wears through from the sliding of the belt it is replaced with a Link-Belt idler with

As stated before, a comparatively small amount of equipment in a cement mill is operated at high speed. For such bearings, however, we have adopted Fafnir ball bearings. One of the first ball bearing installations was on the fans used to supply air to the kilns. These bearings were installed in 1923 and have operated continuously during this time, without any repairs being necessary to fans or bearings. Previous to their installation the kilns were down quite often on account of fan bearing trouble.

We have also equipped the six economizer fans with ball bearings. These fans were equipped with water-cooled bearings on account of heat from the gases which the fans handle. These water-cooled bearings were a source of annoyance and had to be replaced quite often by reason of water lines becoming broken or choked up. These fans are of the overhanging type supported on two bearings. The fans are of large diameter and run at slow speed operating at 220 to 300 r.p.m., and are driven by the same motor that drives the kilns. Our idea in doing this was to increase the draft when the speed of the kiln was increased in order to take care of the larger volume of gases from the kiln, and also to reduce the draft on the kilns when the heat has to be in-

One of the variable-speed drives.
Six Reeves variable-speed transmission units are used on the coal feeder to the kilns. The Allen-Bradley across-the-line starting equipment is mounted on the wall at the right.



On high-speed operations, ball bearings are used.

This Williams pulverizer is mounted on $4\frac{7}{16}$-in. Fafnir double pillow-blocks, with extra dust shields. The dust, shock, and vibration from this drive impose very severe service on the bearings.

creased. These ball bearings have been in operation for three years with the same satisfactory results.

One of the accompanying illustrations shows a Williams pulverizer with Fafnir $4\frac{7}{16}$-in. double-ball pillow-blocks with extra dust seal. These bearings are under exceptionally severe service, as well as subjected to very dusty surroundings, and operate at about 900 r.p.m. They have operated continuously for the past three years, with no replacements of any kind and are oiled only twice a month. We estimate these bearings paid for themselves the first three months they were in operation by the reduction in oil and repairs alone.

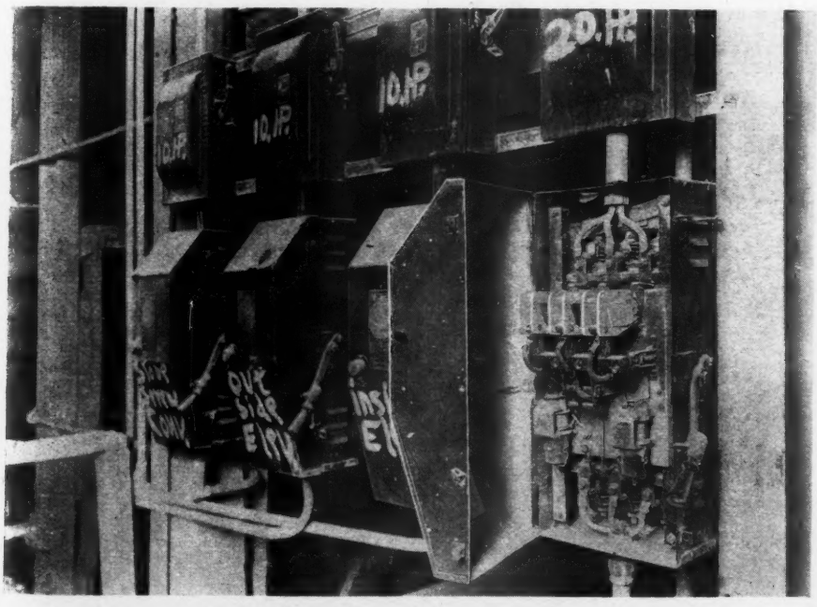
Manufacturers of ball and roller bearings place considerable emphasis upon the saving of power which results from their use. In my opinion the savings that resulted from decreased maintenance and uninterrupted operation are of much more importance. The saving in cost of lubrication is also a considerable item. With plain bearings the interruption of service for replacement costs more than the maintenance labor and material. Also, the shaft wears under plain bearings so that in time a new shaft is necessary, or the worn parts must be cut out. All of these difficulties are eliminated by the use of ball or roller bearings.

In cement mill work care must be exercised to see that bearings of ample size are selected because of the severe service to which they are subjected. Also, particular attention must be given to the dust seal. Most manufacturers of such bearings make several different types of seals, each adapted to varying service conditions. Only the best seal should be considered for cement mill work.

This mill is electrified and is very largely individual drive with a 3,400-hp. connected load. About 160 motors, ranging from 900 hp. down to $2\frac{1}{2}$ hp., are installed. All motors use 440-volt, 60 cycle, three-phase power and a large proportion are operated through Allen-Bradley across-the-line starters with push-button stops. These starters have been adopted as standard on all units of 30 hp. rating and under. Power is generated by a 2,500-kw. and a 1,500-kw Allis-Chalmers turbine supplied with steam from waste-heat boilers. A temporary connection is made with the Louisville Gas & Electric Co. whereby some power is purchased during the peak shipments.

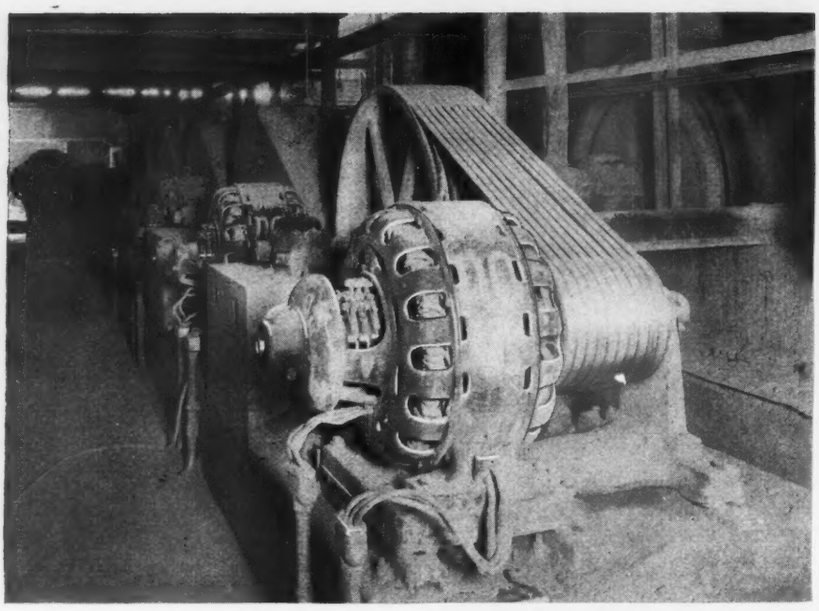
The largest motor, a 900-hp., 180-r.p.m., Allis-Chalmers Hytork synchronous machine, is connected to an 8-ft. x 35-ft. dry ballpeb mill for raw grinding. The starting current is 1,500 amp. and the running current 900 amp. The 35-hp. exciter is driven by a Texrope drive, as shown in an accompanying illustration. We are considering driving this exciter by a separate motor so that the full power of the large motor will be applied to grinding. An Allis-Chalmers bushing-type, flexible coupling connects the pinion shaft to the motor shaft.

Other large motors are two 300-hp., 885-r.p.m. motors driving Bradley mills, a 150-hp. Allis-Chalmers motor direct-connected to a 10,000 g.p.m. centrifugal pump, five 125-hp. Westinghouse motors on 5-ft. x 22-ft. tube mills, three 200-hp. Westinghouse motors on $5\frac{1}{2}$-ft. x 20-ft. tube mills, and some 75-hp. General Electric vertical motors belted to Fuller mills for pulverizing coal. Most of the other motors are Allis-Chalmers make of 10-, 20- or 30-hp. rating. We are standardizing wherever possible on these three ratings not only for motors and controls but also for speed reducers, couplings, pulleys, sprockets, pinions, and so on.



The control apparatus is mounted in groups for convenience of operation.

This illustration shows a group of Allen-Bradley across-the-line starters with push-button stops which control elevators and conveyors. The dust is blown out of these starters periodically. So far as possible, the plant has standardized 10-, 20-, and 30-hp. ratings for driving units, controls, and other auxiliary apparatus, thereby limiting the stock of spare parts.



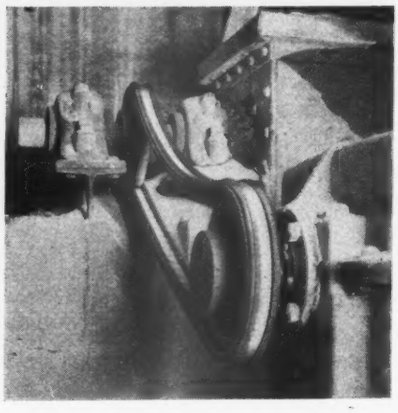
Drives on a battery of five tube mills.
These Texrope drives are of 125-hp. rating and give a reduction of from 580 to 158 r.p.m. The drives have been in operation for more than a year without any adjustment. The first unit has the cover removed to show the drive.

We have also standardized on $2\frac{15}{16}$-in. shafting wherever possible. This includes screw conveyor shafts, conveyor pulley shafts, the few line-shafts in use, and so on. Standardizing on this diameter permits interchange from one unit to another, requires a smaller stock of spare parts, and does not hold us up because a pinion or sprocket will not fit.

All new pinions are heat-treated and supplied by The Tool Steel Gear & Pinion Co. The longer life of the heat-treated pinions more than compensates for the extra cost because of the greater freedom from interruption for changing pinions, as well as having only one installation cost instead of two or three. Any equipment which lasts longer will compensate for any reasonable difference in first cost.

In addition to standardizing the driving equipment we have standardized the construction to simplify inspection and maintenance. For example, the covers on the elevator heads and on the flights of screw conveyors are fitted so that it is not necessary to loosen a single screw or bolt to remove them. However, they fit tightly enough so that they do not slip off accidentally.

A cement plant has comparatively few variable-speed drives. The six pulverized coal feeds on the kilns are controlled by individual Reeves variable-speed units. Variable-speed motors, however, are used to control the speed of the tube mill and coal dryer feeds and kilns.



Close-up view of a chain drive to a screw conveyor headshaft mounted on roller bearing pillow-blocks.

We are standardizing most of our drives connected to a motor through a speed reducer or through a Texrope reduction. Texrope is used on a number of drives where the reduction ratio is not over 6 to 1. The five tube mills shown in an accompanying illustration are driven through 125-hp. Texrope units. These drives have been operating for more than a year without taking up or any other adjustment. Another similar drive on a crusher has been operating for more than 18 months without adjustment. These drives on the tube mills are enclosed in a sheet-metal guard to protect them from dust, although a number of other drives have not been affected by the abrasive atmosphere even though they are not enclosed.

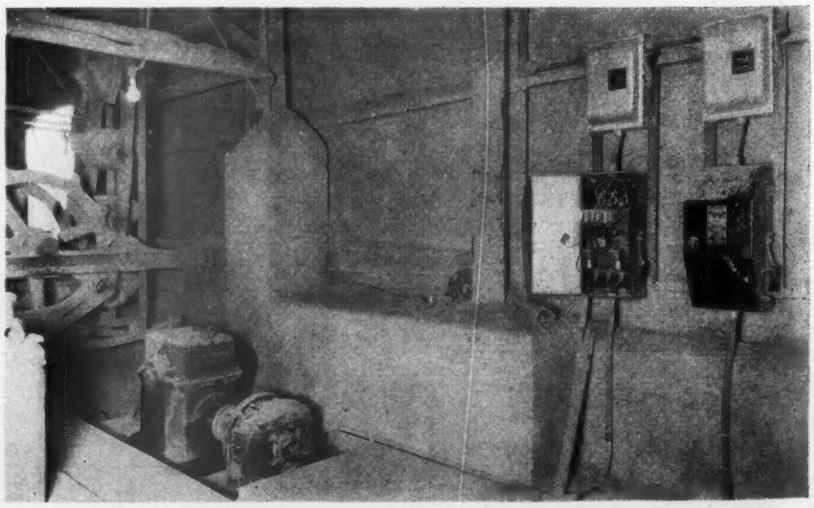
When the centers are longer, Diamond roller chain is used, as, for example, on elevator head and screw conveyor drivers. I find that the open link and sprocket does not wear so much as some of the other types of chains from the particularly severe service and abrasive material in the atmosphere.

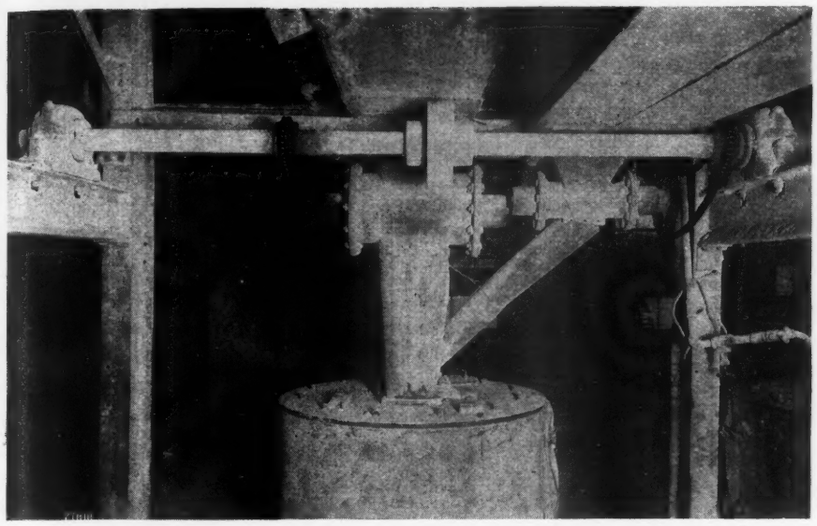
Rubber belts are used to connect the vertical motors to the Fuller mills and on a few other drives.

Equipment operated at a low speed but where the reduction is greater than 6 to 1, such as kilns, dryers, elevators, and belt and screw conveyors, are all driven through a worm reducer connected directly through a coupling, or through roller chains, bevel or spur gears, or various combinations of these.

We are gradually changing over the old speed reducers that were

Speed reducer drive through roller chain to a screw conveyor.
This is a Jones reducer, with Timken bearings on the gear shaft and Strom ball bearings on the worm shaft. The Allen-Bradley control is mounted on the wall at the right. A Trumbull safety disconnect switch is placed ahead of each starter.





One of the few lineshaft drives in the plant.
This 2 11/16-in. lineshaft is mounted on Dodge-Timken pillow-blocks and is connected to the mixing valves through Diamond roller chains.

installed at first to new reducers of more modern design. The past year or two has seen many important changes made in the design of speed reducers. The new Jones worm gear reducers we are using have Timken bearings on the gear shafts and Strom ball bearings on the worm shaft. In addition, new alloys are used in the worm and gear, improvements have been made in the worm design, and the case is much larger and holds several times as much oil as the case on the old reducer, which, however, represented good design when installed. The old reducers are not worn out and perhaps could be kept going for several years. However, I feel that the modern equipment is more substantial, will require less attention, and will give enough more reliable service to warrant making the change now.

As stated before, we have standardized on three sizes of worm speed reducers. Every installation is carefully considered before the particular size of unit is selected. Overloading is probably one of the most common causes of trouble on drives. In considering the load and service the fact that the equipment operates continuously must not be overlooked. Shock loads also have an important bearing upon the rating. To operate satisfactorily, equipment must be amply rated so as to stand up without overheating or undue wear or strain. Although this is also true of any other industry, the continuous service and the extremely bad operating conditions make it much more important in the cement industry and more allowance is made in the rating.

As stated at the beginning, continuous operation is one of the most important factors in cement production. Even the best of equipment is dependent to a large extent upon the reliability of the drive. In our work of rebuilding the plant, especial attention has been given toward providing drives that will be able to give more reliable service under the severe operating conditions which we must face and which can be improved but little. We still have much to do and will probably be working for the next year or two on the changes we have already planned. By that time, perhaps, something better will come out and require the changing of what we have already placed in service. If the change appears to be worth the cost and will add enough to the reliability of operation we will make it.

Bearing Troubles

(Continued from page 483)

pulley over until the leather-faced flange engaged a tight pulley with a similar flange face. Pressure was continuous against the yoke shoes as long as the loom operated, causing serious and rapid wear of the yoke shoes and the pulley hub due to the fact that lubrication was almost impossible.

As this pulley clutch ran as a loose pulley when the loom was idle, all the troubles of the loose pulley were common to it and bushings wore rapidly, until so great a tipping or canting would take place that the clutching action was a failure. Only then were these pulleys repaired, but in spite of delayed repairs, six to ten men were necessary to maintain these looms, with a consequent loss of production per machine that was very high.

An application of our transmission bearings to the pulley in place of the bushing and the substitution of a ball thrust for the yoke brasses cost hardly more than a single repair. The first trial application is still giving satisfactory service.

H. M. CARROLL, *Hyatt Roller Bearing Co., Harrison, N. J.*— For the past several months our engineers have been making power studies in various plants to determine the saving that can be effected by the substitution of the Hyatt lineshaft roller bearings for plain bearings. Some of these tests have proved very interesting, and it has been found that considerable savings have resulted after the installations were made in accordance with our recommendations.

One of our outstanding surveys was made in the weave room of a large New England textile mill on a line containing 100 2 3/16-in. bearings and 10 2 1/16 in. bearings to determine the relative power consumption of plain babbitted bearings and our anti-friction bearings.

Under both tests, no change was made on the system except to replace the 100 2 3/16-in. plain bearings with Hyatt bearings. The ten 2 1/16-in. plain bearings were kept in service during both tests.

As determined from the planimeter readings the power consumption when plain bearings were used averaged 81.20 kw. For the Hyatt bearings it averaged 69.80 kw. showing a distinct power saving of 11.40 kw. or 14.06 per cent in favor of these bearings.

A slightly higher figure would have been realized if the ten 2 1/16-in. plain bearings had also been replaced with the anti-friction type. However, this company's power bill per year is $31,794.96, so that the annual saving effected amounts to $4,769.24, based on the 14.06 per cent saving in power shown by our test. At this rate the entire installation will pay for itself in two and one-half years, on power saving alone.

There is also a considerable saving in the cost of oil and the cost of applying it, as the plain bearings had to be oiled every week, or 52 times a year, whereas the anti-friction bearings require oil only three times a year. However this saving was not included in the above figures.

INDUSTRIAL ENGINEERING

Application and Operation of Electrical and Associated Mechanical Systems and Maintenance of Plant Structures

Published by McGraw-Hill Publishing Company, Inc.

G. A. VAN BRUNT, *Editor*

New York, October, 1927

Helping to Cut the Power Transmission Bill

UNFORTUNATELY, the losses that are most serious in the industrial world are chiefly invisible; that is why they are permitted to occur and to continue. If we could see them, we would soon stop them.

From time to time such of these losses as are involved in industrial wastes are detected and made visible, sometimes through statistical interpretation. When one realizes the magnitude of them he is often astonished.

The head of a large textile plant was once informed by a prominent transmission engineer that the incorrect selection of driving belts in his plant was costing his company many thousands of dollars a year in unnecessary maintenance charges and replacements. He refused to believe the statement until a revision of belts on a "test" section had demonstrated it to be true.

Industry is obliged to pay a tremendous annual bill for its habit of shutting its eyes to losses due to mechanical power transmission through apparatus carelessly chosen, incorrectly applied and poorly maintained.

Individual plants are taxed in no small proportion in order to make up this large total. In the textile mill previously mentioned the loss amounted to more than $30,000 per year simply because of the wrong selection of belts. Thirty thousand dollars per year represents a 6 per cent dividend on a half million dollars of capital stock. It is worth saving.

We believe that this number of INDUSTRIAL ENGINEERING will induce more people to think about their mechanical transmission problems, and thus reveal many dollars of waste that are now escaping unseen in many of our industrial plants.

Consider the Materials Handling Demands of Tomorrow

ONE point often overlooked in the selection of equipment used for handling materials in the industrial plant is that it does not always remain where and as installed. Production changes, shifting of machines, and any of a number of other changes require corresponding extensions, rearrangement, or shifting of the materials handling equipment.

The probability of extensive shifting depends, of course, upon the stability of the particular industry and plant, and numerous other factors. In the case of new industries and new products frequent changes in handling and manufacturing methods may be expected.

The adaptability of the equipment or method of handling to changing or fixed conditions could well receive greater attention in the average industrial plant. Would it be possible to add to the system as installed? Can the equipment be taken down and installed elsewhere without extensive rebuilding? Is it designed to accommodate a reasonable increase in production?

These and many other similar questions should be satisfactorily answered, considering all of the conditions, before any new installation is made. The plant of tomorrow should always be kept in mind when planning for the plant of today.

Do Not Confuse Service With Maintenance

RECENTLY several instances have been noticed where unwarranted demands for service have been made on manufacturers of industrial equipment. In one case a manufacturer sent a service engineer to a large plant nearly 300 miles away, in response to a telegram stating that the automatic control for a large motor was causing serious trouble. The engineer found that a contactor shunt had become loose.

A tactful suggestion that the cause of the trouble could easily have been found and remedied by the plant electrical department was passed over with the remark, "Your company guaranteed this equipment and we expect it to live up to that guarantee."

Doubtless this is an extreme case, but similar, although perhaps less irritating, instances of unjust demands for service are not at all rare.

Every reputable manufacturer is willing to replace parts that are defective, or do anything necessary to make his equipment operate properly. There is, however, a great deal of difference between service and maintenance. No piece of industrial equipment will operate indefinitely without attention. Trying to force a manufacturer to give this maintenance attention, under the guise of a justifiable demand for service, is wrong from every point of view.

For policy's sake a manufacturer may not make a charge for such service calls and it may appear that the user is getting something for nothing. In the long run that is not true. The cost of service, like every other item of expense, must inevitably be reflected in the selling price of the equipment. This means that every purchaser is penalized for the benefit of users who take an unfair advantage. No right-thinking man can find pleasure in the thought that he has helped to bring this condition about.

Engineer a Belt to Its Task

MANY industrial operating men who would not consider laying out a chain, gear, or speed reducer drive without consulting the manufacturer and giving him all the necessary operating data will often blindly select a belt for a particularly difficult drive without asking anyone for advice. Perhaps this is because belts have been used for years and the long acquaintanceship has led him to consider that he knows all that is necessary about a belt drive. However, belting engineers, when investigating reports of unsatisfactory operation, have found many cases where belts were applied without any consideration of fundamental principles.

An example of this lack of knowledge of belts is well indicated by a recent order received by a belting manufacturer. This order called for 2,000 ft. of 3-in. belt for use in an extension of the plant. This manufacturer carries in stock about 30 weights, qualities, and thicknesses of 3-in. belt. Some other manufacturers, by including belts of special tannage, could have supplied about twice as many different 3-in. belts.

The manufacturer sent an engineer to the plant to make a study of the drives and recommend specific belts for the various types of machines driven. Instead of using belt of one width, grade, weight, and thickness, several different types of belts were used and each was engineered to the job in such a manner that the belt manufacturer could practically guarantee the service.

Plant operating men will find it to their advantage to seek expert advice on belt applications, just as they do in the case of other power transmission equipment. They want reliable service from their equipment; this can best be assured by seeking and following good advice.

Carbon-Filament Lamps Have No Place in Your Lighting System

THE modern tungsten lamp has already saved mankind billions of dollars not only in lighting bills but in all the links of electric service from the coal pile to the lighting installation. It has made better lighting possible and, therefore, has conserved vision, increased production, and decreased spoilage and accidents. However, after nearly a score of years since the introduction of the tungsten lamp the carbon filament lamp still survives. More than 18,000,000 carbon lamps were sold last year, notwithstanding the fact that only a few of these had a justifiable economic basis for existence. About 16,000,000 of these were purchased primarily on account of low first cost or unusual bulb shape.

In the earlier years of the tungsten lamp the public was systematically informed that tungsten lamps provide "three times as much light for the same energy consumption." This educational work has practically ceased so that the new generation is, perhaps, not entirely familiar with this point. In any event, the use of carbon filament lamps for general lighting purposes results in a direct waste of money.

Perhaps 2,000,000 carbon lamps were purchased on account of a belief that they are still more rugged than the tungsten lamps—as they used to be. Recently, however, rough-service tungsten lamps have become available so that in most cases carbon lamps can be satisfactorily superceded by a more efficient type.

The use of carbon lamps is not justifiable excepting in very special cases that do not ordinarly arise. Elimination of waste is one of the slogans of the day, and waste certainly has no place in lighting or in electrical development.

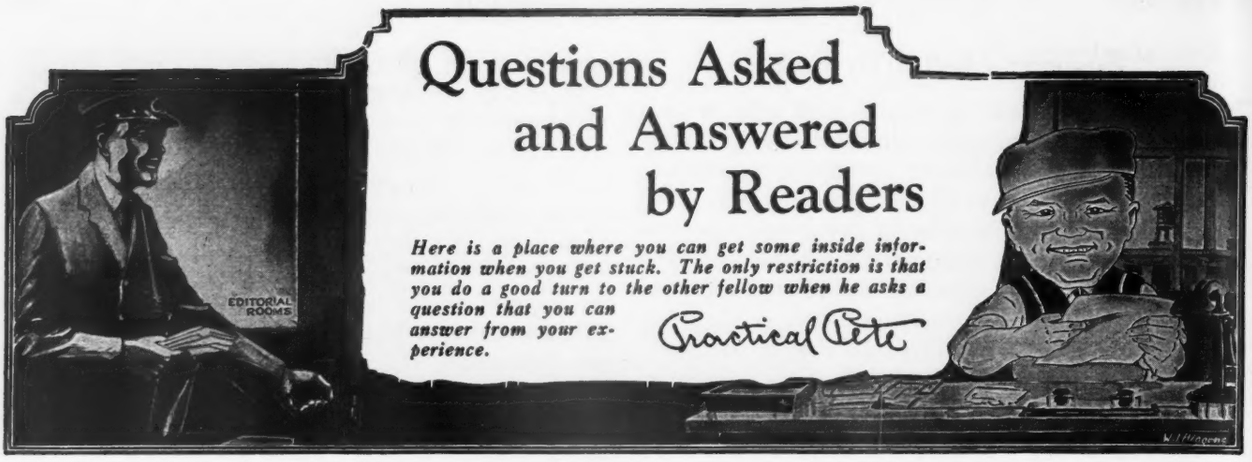
Standardization of Electric Motor Frames

PROGRESS is being made in the standardization of important dimensions governing the interchangeability of electric motors of different makes. According to an announcement by the American Engineering Standards Committee, two prominent organizations, the American Society of Mechanical Engineers and the National Electrical Manufacturers Association, have accepted joint leadership in the development of such standards.

Machinery everywhere is more and more becoming motorized, being driven either by self-contained electric motors or adapted to easy application of motor drive upon installation. This is particularly noteworthy in the case of metal and woodworking machinery of every description, refrigerating machines, foundry equipment, printing presses, steel mills, and so on. However, owing to variation of dimensions in different makes of motors, specific and detailed information is often necessary with each new application. In some cases significant changes in design have been required to accommodate some particular make of motor.

The National Machine Tool Builders Association, which found diversity in motor dimensions a problem of particular difficulty, filed the original request to have the subject taken up by the American Engineering Standards Committee. At a conference, to which all parties interested in this subject were invited, the scope of the work was defined to include standards for shaft height, distances between bolt holes at right angles to, and parallel to, the shaft, certain combinations of shaft height and distances between bolt holes, and maximum diameter and length of motor.

Undertaking of this important work by the N.E.M.A. and the A.S.M.E. is good news to operating men, for it will eventually lead to the solution of a troublesome problem.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

QUESTIONS
Who Can Answer These?

How Much Power Can Be Saved by Realigning Shafting?

We wish to increase the load in one of our old mills. Our engine is loaded to capacity and I should like to know (1) if readers have found that the power saved by carefully realigning all shafting in their plants makes a noticeable reduction in the total amount of power consumed, and if so, about what percentage? (2) After the shafting is properly lined up, how often should it be checked? (3) Is there a simple but accurate method that may be employed to check the alignment?
Gt. Punxsutawney, Pa. P. F. D.

Power Factor of Generator Used as a Motor

As all the electric current used in our plant in the future will be purchased, we would like to make use of an a.c. generator that was formerly driven by a steam engine, as a synchronous motor. This generator was rated at 80 per cent lagging power factor. Will its power factor be leading or lagging, when used as a motor? Will some reader please explain why?
Northampton, Mass. L. G. D.

Deterioration of Pipe Drainage System

It is supposed that much of the deterioration in some of our pipe drainage system is due to electrolytic action caused by our plant haulage system, which is operated on direct current. Insulating the joints between some of the pipe sections, electrically connecting all adjacent pipe ends and connecting the pipe line to the tracks are some of the remedies that have been suggested for the trouble. Whether or not readers believe the railroad is causing the trouble, what can we do to stop the deterioration of the pipe?
Pittsburgh, Pa. V. McL.

Inspection of Transformer Oil

I wish readers would give me their opinion on the following questions: (1) How often should the oil in transformers be inspected? (2) What are the minimum safe dielectric values of such oil for various operating voltages, as determined by the sphere gap testing equipment? (3) What differences may be expected from such tests on samples taken from the top and the bottom of the transformer? (4) Is there any limit to the life of transformer oil if tests show it to be clean and its dielectric value satisfactory? (5) Are periodic tests of the insulation resistance from the high side to ground, from high to low side and from low side to ground of any value on oil-filled transformers?
Cleveland, Ohio. J. M. S.

Is this Ground Detector at Fault?

When our three-phase a.c. distribution system was revamped, so that all circuits could be controlled from a central point, a three-phase, Type TG, Westinghouse electrostatic ground detector was connected to the main 2,300-volt bus. When installed the dot on the moving vane coincided with the etched ring on the glass cover but recently it has indicated a ground between two phases that I cannot locate with a Megger. When the bus is entirely disconnected, the vane rotates about 180 deg. before coming to rest, off center, but if cut out of service for several days, it will take the zero position. Will readers who have had similar trouble tell me if this action indicates faulty condensers? Or is it due to the unbalancing caused by a heavy, single-phase heating load?
Kearny, N. J. A. D. S.

Automatic Starting of Motors After Failure of Power

We have six pumps in our mine driven by three-phase, 60-cycle, 440-volt, squirrel-cage induction motors ranging in size from 3-, to 7.5-hp. rating. The current supply to these motors is frequently interrupted by trouble in the feeder lines to the mine; also slate-falls in the mine often break one of the three-phase wires leading to one of the motors. Will readers kindly tell me what methods to employ so as (1) to protect the motors from overloads and single-phasing, and (2) automatically start the motors upon restoration of power after failure?
Eckman, W. Va. D. C. W.

ANSWERS
Received to Questions Asked

Trouble in Setting Circuit Breakers

We have had difficulty in accurately setting our three-phase, 550-volt oil circuit breakers, which range from 80- to 400-amp. rating. I shall appreciate it if readers will tell me the best method of making this adjustment, by the use of a phanton load. Can a water rheostat be used as the load, or is some other device more suitable?
Vancouver, B. C., Can. A. M. S.

ANSWERING A. M. S.'s question, it is possible to use a water rheostat in the test circuit, but if a job can be done with some other type of resistance, it is highly advisable to do so, for home-constructed water rheostats are ordinarily dangerous to life and equipment and besides are not well adapted to this type of testing.

In setting circuit breakers, I use the General Electric meter-testing rheostat with rheostat control. This instrument can be purchased with or without the rheostat, but it is advisable to invest a few extra dollars to obtain the finer control.

In connection with the rheostat I use a stop watch and ammeter, and through their use a very accurate setting can be determined. I might add that our oil circuit breakers are protected through the G.E. I A 201 overload relays, and the settings obtained are very accurate.

E. J. Morrissey.
Chief Electrician,
Western United Gas & Electric Co.,
Aurora, Ill.

IN REPLY to the question by A. M. S., the most dependable practice to assure the proper operation of an oil switch is to apply to the tripping coil, from a separate circuit, the load desired for the breaker to open. At the same time allow the entire oil breaker to function, in order to make certain all parts are operating.

To set an oil breaker by placing the adjustment indicator, or pointer, at the figures marked on the switch is not good

practice, as the breaker may operate at a value below or above the desired load. I presume that the breakers in question are operated under overload conditions from the secondaries of current transformers. In this case a phantom load of 5 amp. will suffice for the testing of the tripping point, excepting where circuits are carrying an overload current that is above the rating of the current transformer.

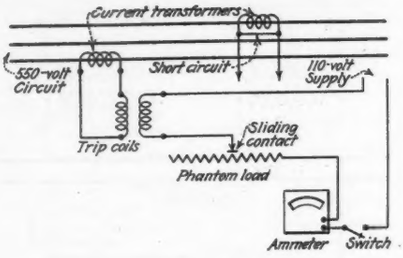
In setting an oil breaker it is not very handy to use a bank of lamps for the test load, but about 50 to 60 ft. of No. 22 Nichrome wire wound around a porcelain tube and cemented to keep the turns in place should prove satisfactory, allowing enough exposed surface to slide a moving contact over the turns. This sliding contact may be made from a fuse clip and an ordinary water kettle cover handle. When a 110-volt test circuit is used, any load from 1 amp. up to 20 amp. can be obtained.

As indicated in the accompanying illustration, all that is necessary to test the trip coils is a phantom load, one ammeter, a single- or double-pole single-throw switch and a 110-volt single-phase circuit.

The test is made by first short circuiting the secondaries of one current transformer and disconnecting the secondaries from the tripping coil. Connect one side of the 110-volt circuit to one terminal of the single-pole switch. The other side of this switch is connected to the ammeter and the second terminal on the ammeter is connected to the phantom load. The other side of the 110-volt circuit is also connected to the phantom load. Open the single-pole switch, move the sliding contact along so that most of the Nichrome-wire coil is placed in circuit, and then switch on the 110-volt supply. Next close the single-pole switch and observe the ammeter. Adjust the moving contact until the desired load is obtained. The ammeter reading, of course, is to be multiplied by the current transformer ratio in order to determine the amount of line current needed to trip the breaker.

When the desired load has been obtained, open the switch in the test circuit, disconnect the side of the phantom load connected directly to the line, and connect this terminal to the trip coil. The other end of the trip coil should be connected to the line. Close the oil circuit breaker, then close the switch in the test circuit, placing the test current through the coils.

Should the oil breaker open immediately, do not take it for granted that it trips at the proper point. Lower the current in the test circuit until a point is reached where the oil breaker will not open when the test current is applied. Then gradually adjust the current setting upward, at the same time increasing the current in the test circuit until the desired tripping value is reached; until it is finally determined that the oil switch will not open at any load below that which you desire it to



How to connect a phantom load to a trip coil.

operate. When each tripping coil is tested in this manner, it is definitely known just what load will trip the circuit.

It is a good practice to keep a record of all these tests and settings made on each breaker for reference. The usual practice is to keep an "as found record" and an "as left record," which may be very useful to refer to from time to time.

E. J. ELVISH.

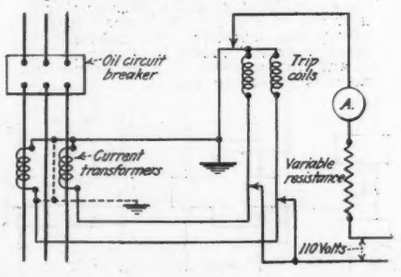
Maintenance Inspector,
Kaministiqua Power Co.,
Fort William, Ont.

IN REPLY to A. M. S.'s question, assuming that the oil circuit breakers used are hand operated and are opened by current from a current transformer supplied to a trip coil, and that no relays are used, I would suggest the following plan:

First, the current transformer ratio should be checked to find the current flow required in the trip coils to operate the breaker at the desired load. Then the secondaries of the current transformers must be short circuited as indicated in the diagram by the dotted lines, and the circuit to the trip coils opened. After doing this and using a 110-volt source of current supply, an ammeter and a suitable resistance can be placed in series first with one trip coil and then with the other. Then set the plunger on the trip coil at a point where the breaker trips out when the required amount of current is allowed to flow in the coil.

For instance, let us assume that the current transformer ratio is 60 to 1 and the load at which the breaker is to trip is 300 amp. Then the current in the trip coils necessary to trip the breaker at a 300-amp. load can be calculated as follows: $60:1 = 300:x$; $60x = 300$; $x = 5$ amp. In this case it would simply be necessary to set the plunger of the trip coils to a point where the breaker would trip out when 5 amp. is flowing in the trip coils.

How to connect a test circuit to the trip coils of a circuit breaker.



FRANK C. AMMANN.

Plant Electrician,
Sioux City Gas & Electric Co.,
Sioux City, Iowa.

Checking Condition of Elevator Cables

We are using the ordinary 6-19 cables on most of our elevators and I wish readers would give me some suggestions on inspecting them for condition. Can our maintenance men determine when these cables need to be replaced by counting the broken strands? If not, what other methods or tests can we employ that will safely determine this point? I shall appreciate any help from readers.
Auburn, N. Y. H. W. J.

IN REPLY to H. W. J.'s question, the usual method of checking the condition of elevator hoist cables consists primarily in examining them carefully for broken wires. This examination must cover particularly all portions of the cable that pass over the sheaves or drums, because the wear and subsequent breakage of the cable appears, under ordinary conditions, on those sections of the cable that are subjected to repeated bending around the sheaves.

When the elevator machine is located in the basement it will be necessary to go into the overhead work and examine that section of the cable which passes around the overhead sheaves, but never gets down to the machine. With overhead machines, unless they are roped in a 2:1 ratio to the car and counterweighted, the entire length of rope subjected to bending may be examined at the machine.

When the car and counterweight are roped 2:1, attention must be paid to the sections of the rope near the multiplying sheaves on the top of the car, or under it, as the case may be, and the top of the counterweight.

If more than five or six of the individual wires that make up the strands are found to be broken per inch in a given section, it is time to renew that particular cable.

Cables may wear considerably and yet not show any broken wires. By this I mean that a thinning or flattening of the wires may take place, imparting a bright, shiny appearance to the whole cable. At this stage of its life the cable must be watched very carefully, as breakage of the wires is imminent. On the other hand, broken wires may appear when there is hardly any sign of wear on the cable. In such cases it is generally an indication that the rope has been overloaded, or that the wrong kind of cable is being used. The cable may be too stiff, or it may be too large for the diameter of the sheaves with which it is used.

J. M. WALSH.

Asst. Chief Engineer,
Gurney Elevator Co.,
New York, N. Y.

Cutting Out Damaged Coil in Winding

Will some reader please give me a diagram of a chorded split-loop winding showing the method of cutting out a damaged coil? I should also like to know if this type of winding does not have a much longer lead throw than the straight loop winding. Can it be wound with two wires in hand and connected to a commutator with twice as many bars as coils? Would the method of cutting out a coil be the same as when wound with one wire in hand? J. B.
Los Angeles, Calif.

REGARDING J.B.'s question, a chorded split-loop winding can be wound with any number of wires in hand; that is, two when bars $\times$ slots $=$ two, or three when there are three times as many bars as slots, and so on. The lead throw of any type of winding depends on the position.

A diagram is not needed to show how to cut out a coil, for all that is necessary to locate the defective coil is to trace its leads to the two commutator bars to which the coil connects. Then cut open the defective coil and put a jumper across the bars to which the coils connect.

The method of cutting out the coil is the same regardless of the number of wires in hand.

A. C. ROE.

Renewal Parts Engineering Dept.,
Westinghouse Electric & Manufacturing Co.,
East Pittsburgh, Pa.

What Causes Blowing of Fuses on Transformer Bank?

We have two 50-kw. transformer banks serving separate heating loads and when they are connected in parallel on the secondary side the fuses blow on one bank. Everything on the nameplates of both banks corresponds except the polarity. One bank is marked Subtractive, while the other is marked Additive. Will readers explain the meaning of these markings, and tell me if this difference in polarity has anything to do with the blowing of the fuses? H. B. D.
Lynn, Mass.

IN ANSWER to H. B. D.'s question, evidently the polarity markings are wrong or they have been misunderstood. As the additive polarity is exactly opposite to that of the subtractive polarity of transformers, it will first be necessary to ascertain whether the transformers are tied together on the same phase. If they are, then reverse either the primary or secondary side of either one of the transformers that are banked together.

When transformer leads are marked in accordance with the National Electric Light Association rules, the polarity of a transformer is subtractive when H_1 and X_1, as indicated in Fig. 1 in the accompanying illustration, are adjacent, and additive when H_1 is diagonally opposite X_1, as in Fig. 2.

Single-phase transformer nameplates should in all cases be marked as either of subtractive or of additive polarity, so as to indicate definitely the polarity of the transformer to which the nameplate is attached. The older types of transformers, however, did not have these markings.

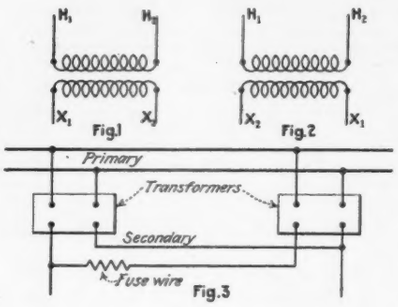
Two simple tests for the determination of polarity are recommended as follows:

First Test—For small transformers, where current values are not excessive, connect the primaries in parallel to the supply circuit. Then connect the secondaries in parallel, with a fuse in series with one line, as shown in Fig. 3. If the transformer polarities are the same, the fuse will remain intact when the primary voltage is applied; otherwise the fuse will blow before the transformer is damaged.

Second Test—For large transformers, where the current is relatively high, it is not advisable to use the fuse-wire test. In this case the same general arrangement of connections should be used, but the fuse wire should be replaced with a potential transformer that is suitable for twice the secondary voltage, a lamp bank, or a voltmeter. No voltage at the fuse position, Fig. 3, indicates that the transformers have been correctly connected.

On the other hand, if voltage is observed, reverse either the primary or secondary leads of only one of the transformers. H. J. ACHEE.

Superintendent,
Water & Light Dept.,
Woodward, Okla.



How a fuse is used to test the connections between the secondaries of additive and subtractive transformers.

ANSWERING the question by H. B. D., it is assumed from the description given of the trouble that the fuses blow as soon as the transformer banks are paralleled. The questioner does not state whether the banks are single phase or three phase. The general explanation can, however, be given on the basis of single-phase banks, since the principle involved is the same. Fig. 1 shows a transformer with leads brought out to give subtractive polarity; Fig. 2 shows lead brought out to give additive polarity.

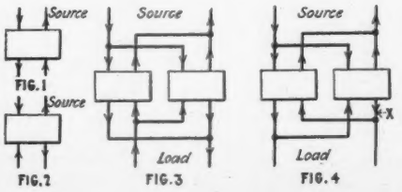
In both of these cases the source is assumed to give a current flow through the transformer in the same direction, the arrows indicating the direction of instantaneous flow. Fig. 3 shows the correct connections for paralleling two banks when one transformer is of subtractive and one of additive polarity. Fig. 4 shows two banks incorrectly connected when the polarities are different. It will be noted that on the load side there exists a dead short circuit, consequently the fuses will blow.

In paralleling transformers as indicated in the illustration, a lamp bank or voltmeter should be used on the low-voltage side, say at X in Fig. 4, and the leads only connected permanently when the voltage is zero, or approximately so, between the lead ends. Should the voltage be higher than, say, 600 volts, a potential transformer should be used. In any event the instrument potential transformer, or perhaps in some cases a lamp bank, should be arranged to accommodate twice the voltage of one bank. C. OTTO VON DANNENBERG.

Electrical Division,
Industrial Engineering & Management Corporation,
New York, N. Y.

Additive and subtractive transformer connections.

A subtractive polarity transformer is shown in Fig. 1, one of additive polarity is shown in Fig. 2. The correct way of connecting additive and substractive polarity transformers is shown in Fig. 3, and an incorrect way of connecting them is shown in Fig. 4.



Can Formation of White Incrustation on Brick Be Prevented?

Our main office building is built of pressed red brick, most of which is covered with a white, salt-like incrustation that is very unsightly. Part of this can be brushed off, but it soon forms again. We do not want to paint the building if it can be avoided and I should like to know if there is any treatment that can be applied to the bricks that will prevent the formation of this white coating. R. P.
Chicago, Ill.

REFERRING to the question by R. P., there is a material on the market called Brixope which is sold for the purpose of removing and preventing white incrustation on brickwork.

After as much dirt and white stain as possible has been dry brushed from the wall the prepared material is scrubbed on and cleans off the remaining efflorescence and at the same time waterproofs the wall. This material is largely used in the building business for this purpose. It is claimed that the results obtained by this material are more permanent than if an acid substance were used. In addition it will not burn or harm any of the materials commonly found on a wall.

IRVING KASS.

New York, N. Y.

IN REPLY to the question by R. P., after rather extensive observations of brick walls, I believe that the white incrustation he mentioned is due to a lime formation that originates in the brick and mortar. To remove the white

incrustation, wash the wall with weak muriatic acid.

The affected bricks usually appear in groups, and those places in the wall where water can enter even to a limited extent are generally the locations of the greatest amount of incrustation.

To prevent the water from seeping into the wall, calk the joints and cracks with some form of asphalt or elastic roofing cement. After this is done, the wall surface should be treated with some suitable substance that will prevent the returning of the white incrustation.

H. D. FISHER.

Plant Engineer,
New Haven Board & Pulp Co.,
New Haven, Conn.

ANSWERING the question by R. P., although painting the wall may prevent the formation of the white incrustation for a time, it will be necessary to repaint the wall as the paint wears off. This repainting process in some cases will be rather expensive.

There is another method, however, which I would recommend in preference to all others. After cleaning the walls of all incrustation and other foreign matter, apply a waterproof oil in the same manner as you would apply paint. By properly working the oil into the pores of the brick and cement mortar, a waterproof wall will result. There is a waterproof oil sold for the specific purpose of preventing the formation of this white incrustation on the surface of brick walls.

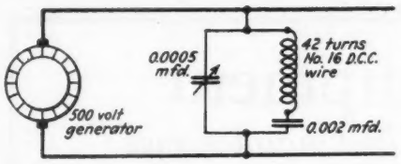
NATHANIEL W. BLANCHARD.
Inwood, N. Y.

Eliminating Radio Interference from D. C. Generator

Interference with radio reception in our community has been traced to one of our 100-kw., 230-volt, 275-r.p.m., Type N, engine-driven Westinghouse generators. We ground the commutator and adjusted the brushes and holders so that there is no sparking, but the only way that the trouble can be stopped is by pulling the main switch, or by reducing the voltage from 230 to 160. When the voltage is raised, the trouble returns. The radio interfence seems to be greatest at one end of the engine stroke; in town it is possible to count the revolutions of the engine on a radio set. I believe that the engine speeds up at the end of one stroke, thereby increasing the generator voltage. If condensers are a practical remedy for the trouble, what size should they be? How should they be connected to the generator? What other method could be used to rectify the trouble? We are very anxious to get this situation cleared up and I shall appreciate any help you can give me.
Vandergrift, Pa. G. J. K.

IN ANSWERING G. J. K.'s question, he should not have any real difficulty in clearing up this radio interference if he will follow these suggestions.

First, eliminate as much of the sparking of the brushes as is possible. Second, I would recommend the use of a Tobe filter for that particular size of d.c. generator. This filter should be installed according to the directions that come with it. These filters are very compact, measuring 10 in. x 6 in. x 2 in. Third, wind an inductance coil made up of 42 turns of No. 16 d.c.c. wire on a 3-in. diameter core, and connect it as shown in the illustration with a 0.005-mfd. variable condenser, and a 0.002-mfd. fixed condenser across the generator leads.



One way of preventing radio interference by employing an induction coil, a fixed and a variable condenser.

GEO. R. CONKLIN.
Radio Engineer,
Southwest Light & Power Co.,
Elk City, Okla.

Why Does This Commutator Wear Out of Round?

The life of a new commutator on one of our 3-hp., 230-volt, d.c., 1,150-r.p.m., style SK, Westinghouse motors is very short. This motor, which is belted to a suction fan, is located in a room where lead is melted and cast into bars. In an attempt to overcome our trouble we have tried different brushes, undercutting the commutator, and used good armatures from other machines, but about every three months the commutator becomes egg-shaped. Is it the acid or gas fumes, or something else that is causing the trouble? I shall be grateful for any information that readers can give me.
Chicago, Ill. F. J. C.

REPLYING to the question by F.J.C., a commutator wearing egg-shaped is rare indeed. This trouble may be caused either by the belt action or the acid fumes.

If it is found that the belt is causing the trouble, the use of an endless belt and the elimination of any belt slap should remedy trouble from this source.

It is quite probable that the acid and gas fumes in the atmosphere, which attack mica insulation, may be the cause of the commutator wearing egg-shaped. In order to avoid this trouble the mica should not be undercut, but run the commutator with the mica flush, for the dirt that collects in the slots soon becomes contaminated with acid, and then, of course, the mica and segments will be affected. The fumes in the air will also attack the V ring, and cause it to shrink. As this action will cause the segments to loosen, it may be the cause of the trouble experienced.

W. E. WARNER.
Shefford, Bedfordshire, England.

IN REPLY to F. J. C.'s question, there may be some electrolytic action causing the commutator trouble but in this case it surely would affect the whole surface of the commutator and not part of it. In case the fan is belt driven the belt lacing might be the cause of the trouble. High mica or soft copper in the bars would also cause trouble. Rubbing the commutator lightly with vaseline about once a week might lessen the trouble.

I would suggest that F. J. C. test the armature for balance, and eliminate all vibration possible. At this time the air gap can also be checked. Besides testing all fields for the short-circuited coils and grounds it might be well to check the brush spacing and be sure that each brush has the same thickness.

If acid fumes are the cause of the trouble, the obvious remedy will be to inclose the motor so that these fumes cannot enter it. One sure way of determining whether the fault is due to inherent defects in the machine or to the nature of the drive would be to replace this motor with another one, in order to observe what effect this particular drive has on the new motor.

GRADY H. EMERSON.
Birmingham, Ala.

ANSWERING the question by F. J. C., the trouble referred to may be due to several causes, the most common being high mica, looseness, or an unseasoned commutator. The questioner states that the mica has been undercut; so it is reasonable to assume that the trouble is not due to high mica. If, however, the commutator is not tight, that is, if the bolts are not drawn up as far as possible, heating will cause it to expand and change its shape.

From the description of the operating conditions it does not seem unlikely that the room temperature may at times be higher than the usual conditions and so cause the whole machine to operate at a higher temperature. F. J. C. should make sure that the holding bolts are as tight as possible. It is, of course, not possible in the usual case to go to the trouble of removing the commutator and heating it in an oven; so the following methods are suggested:

(1) The commutator may be heated with a gasoline torch, preferably with the armature mounted on horses and slowly revolved while the flame is moved over the surface of the commutator parallel to the shaft. This method is used by many repair men, although it requires considerable experience and judgment to avoid overheating and should be carried out with much caution.

(2) Another method is to shift the brushes very slightly so that they will spark when the motor is operating. The motor is allowed to run for about an hour and then shut down and the bolts tightened. It is then allowed to run for another hour and the same procedure followed. In this way the expansion can be taken up gradually.

(3) A method used by a manufacturer consists in driving the motor by another one and bearing down on the commutator with a maple block. This method is very readily carried out in a repair shop and heat is generated quite rapidly, so that the bolts can be tightened within a short time; it also keeps the surface in fairly good shape. With this method it is, of course, necessary to remove the brushes.

With any of the foregoing methods it is necessary, after the tightening has been completed, to resurface the commutator.

C. OTTO VON DANNENBERG.
Electrical Division,
General Engineering & Management Corp.,
New York, N. Y.

New Equipment
for plant operation and maintenance

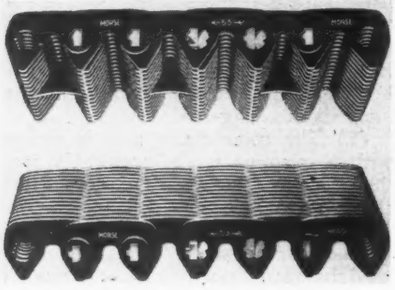
Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Rocker-Joint Chain

ANNOUNCEMENT has been made by the Morse Chain Co., Ithaca, N. Y., of an improved chain. The improvements consist principally of changes in the design of the rocker joint.

The new 55 type chain will operate on present design of sprockets, the new link being the same length and height as the old. The new joint, as shown in the accompanying illustration, operates on the same principle as the original Morse rocker joint. The seat pin, at the left, has been enlarged to give greater bearing surface and also to make it a stronger transverse member to hold the chain together. The rocker pin, at the right, has been changed in contour, thereby giving a better surface contact with the links.

The combined joint members give a more nearly round hole with reduced clearance, holding the links more securely on the pins. The joint pins are about 8 per cent heavier and the complete chain weighs twice the pitch per inch foot. The breaking strength, it is claimed, has been increased about 50 per cent.



Morse Rocker-Point Chain

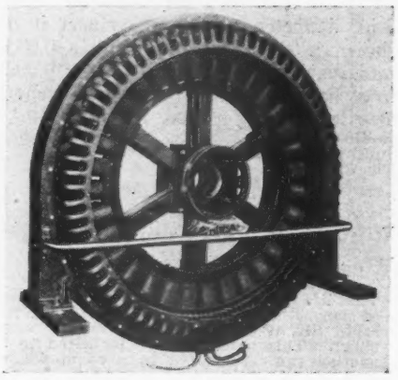
Arc-Welded Synchronous Motor

A NEW low-speed synchronous motor, called the Type HR, has recently been placed on the market by the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. This motor, which is of arc-welded construction, has been specially designed for ease in handling and ease in assembling in the field.

Material reduction of the excitation, a starting torque of 50 per cent and a pull-in torque of 40 per cent are claimed as features of this new motor which is shown in the next column.

The shape of the rotor arm in this new motor is such that a large amount of air is set in motion, and this air is so directed that it not only passes through the stator coils but also passes over a large area of the stator laminations. By means of different weight rings bolted to the rotor rim, six possible values of flywheel effect are available.

This motor is said to be particularly desirable for driving refrigerating machines and air compressors; when direct-connected it is equally desirable for driving jordans, pulp grinders, pumps and other slow-speed machinery of this character.



Westinghouse Type HR, Low-Speed Synchronous Motor

Lifting Magnet

MARKETING of a lifting magnet, known as Type SA, has been announced by the Electric Controller & Manufacturing Co., Cleveland, Ohio. The coil spider of composite construction, with a body of cast steel and a flange of cold-rolled brass, provides greater strength and better lifting capacity, it is claimed, than a one-piece, cast-brass spider.

In the new design the outer pole shoe is extended upward to fit against a machined surface on the outside of the magnet housing, giving greater strength for the purpose of preventing pole shoe breakage.

A steel plate ½ in. thick is bolted in place at the top of the magnet to prevent injury to the incoming lead wires from the crushing effect of the crane hook and chains.

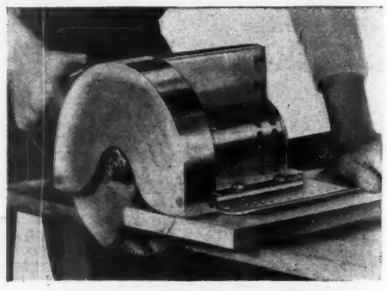
Electric Controller & Manufacturing Co. Type SA Lifting Magnet

Portable Electric Saw

A LIGHT portable electric saw is being marketed by the Lee Pattern Co., 130 13th St., Milwaukee, Wis. It weighs 6 lb. and it is said will cut lumber up to 1 in. in thickness.

This saw is primarily a one-hand tool, and due to its shape, it can be laid down on any of its four sides without rolling over.

The saw is equipped with an automatic guard that is said to insure safety at all times. If necessary, the guard can be changed for the use of a left-handed workman. A patented ridge is provided for gripping the machine in a vise, so that it can be used as a regular bench saw. This vise grip can also be used as a hand grip for pushing the saw through the work.



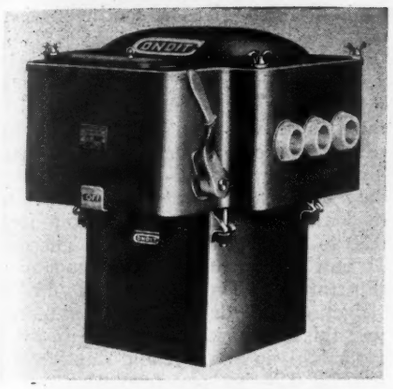
Lee Portable Electric Saw

Oil Circuit Breaker

A MANUALLY operated indoor oil circuit breaker known as Type E-20, specially designed for the protection of large motors and for general utility in the industrial field, has been placed on the market by the Condit Electrical Manufacturing Corporation, Boston, Mass. The application of a thermal overload trip device to this oil circuit breaker, affording time lag overload protection, is one of the distinct features.

The housing and frame are of heavy-gage pressed steel, the housing being firmly welded to the frame on all four sides completely inclosing all of the live parts. The cover is a single piece turned at the edges.

Both movable and stationary contact members are extra heavy, the movable contact being strongly supported in a heavy carriage and provided with helical springs which maintain a high pressure on closing and facilitate the opening of the movable member.



Type E-20 Oil Circuit Breaker Manufactured by the Condit Electrical Corporation

The circuit breakers are equipped with a position indicator, which indicates whether they are in the open or the closed position.

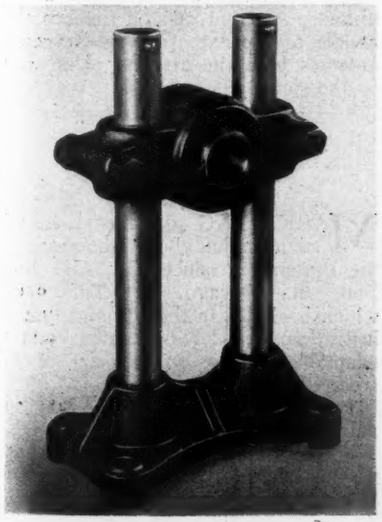
Overload tripping is accomplished by the use of a mechanical thermal tripping device used in conjunction with current transformers. This Type E-20 circuit breaker is furnished for 400 amp. or less, three poles, and has an estimated interrupting capacity of 2,400 amp. at 2,500 volts.

Adjustable Outboard Bearing

DISTRIBUTION of a line of adjustable outboard bearings, one of which is shown in the accompanying illustration, is announced by the Boston Gear Works Sales Co., Norfolk Downs (Quincy), Mass. These outboard bearings are furnished either with or without bronze bushings and accommodate shafts ranging from ¾ to 2⅞ in. in diameter.

Boston duplex bearings can be used in these adjustable supports which are of sturdy construction. These bearings are used for special or temporary construction, and for countershafts or jackshafts and similar purposes.

Boston Adjustable Outboard Bearing

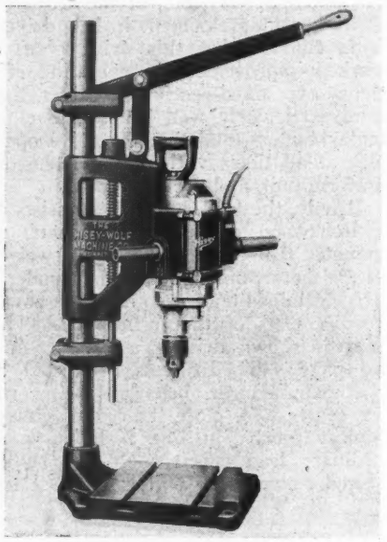


The over-all heights of these units vary from 5½ to 12⅜ in., and the base dimensions from 2⅜x4⅛ in. to 5¼x10⅜ in. The maximum base-to-center distance is from 4¼ to 10¾ in. and the minimum from 1⅞ to 4½ in. The various units weigh from 2¼ to 28 lb., according to the bore.

Drill Stands

NEW drill stands can now be supplied for post or wall mounting, in addition to the conventional bench design by the Hisey-Wolf Machine Co., Cincinnati, Ohio.

The stands, one of which is shown in the illustration, are made for all sizes of Hisey electric drills from ¼-in. to ⅝-in.



Hisey-Wolf Electric Drill Stand

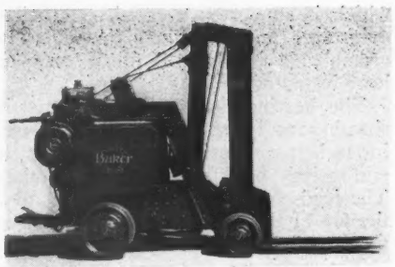
capacity. They are designed so that the portable drills can be attached without moving a single part of the machine. The facing surfaces of the supporting bracket, as well as the drill housing, are machined to insure proper alignment of the drill in the stand.

Tin-Plate Truck

A NEW type of tin-plate truck has recently been put on the market by the Baker-Raulang Co., Cleveland, Ohio. This truck, which is shown in the accompanying illustration, has a capacity of 5,000 lb. of sheets and is small enough to be driven inside the average box car.

The driving axle is of the full floating type, with a 17½:1 worm gear reduction. The motor is mounted on a cradle cast integrally with the axle housing. To provide easy steering, the knuckle pivots are in line with the tire centers.

The controller is the standard Baker all-metal type with renewable segments and renewable fingertips. An automatic switch of the quick-break type with auxiliary carbon contacts is provided as a safety feature. It is interlocked with the controller and prevents the operation of the truck except by a conscious and sustained action on the part of the operator.



Baker-Raulang New Type Tin-Plate Truck

The hoist consists of two drums, either of which may be driven by a series-wound motor. A selector switch operates a set of magnetic clutches and determines which drum will be driven when the power is applied. One cable hoists the carriage and forks and the other tilts the superstructure. When picking up a load, the superstructure is normally vertical and the forks will lift high enough to stack loads one upon the other. When unloading, the superstructure may be tilted a little forward of the vertical position in order to bring the points of the fork prongs into contact with the floor.

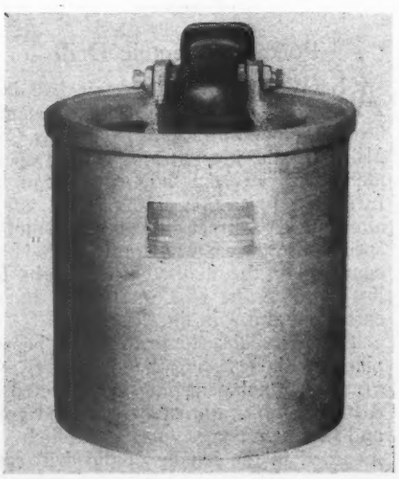
Limit switches are provided to open the hoist-motor circuit at both limits of travel of the carriage and of the superstructure.

Electric Melting Pot

A NEW electric melting pot has been introduced by the General Electric Co., Schenectady, N. Y., for melting solder, lead, babbitt, tin and the like. It has a capacity of from 27 to 40 lb., according to the metal to be melted. This pot may be operated on either a 110-volt or a 220-volt alternating or direct-current circuit and is made in two ratings—750 and 1,000 watts.

The new pot is the smallest size of the G.E. RP form E line. It consists of a sheet-steel cylindrical casing 10 in. deep and 9 in. in diameter, inside of

G.E. Small-Capacity Melting Pot



which is supported a cast-iron crucible 4 in. deep and 6 in. in diameter. The crucible is insulated with a compact heat insulator.

The heating units are of the cast-in sheath-wire type, and one unit is used in each pot, dissipating 750 watts in one rating and 1,000 watts in the other. The leads of the unit are brought over the top of the pot into a connection box fixed to the unit itself.

The maximum melting temperature of this pot is 950 deg. F., and it has a capacity of 30 lb. for 50/50 solder, 40 lb. for lead, 37 lb. for babbitt and 27 lb. for tin.

Third Rail Insulator

A THIRD rail insulator unit of new design has been developed by the Railway & Industrial Engineering Co., Greensburg, Pa. The unit is built up from the Type T support with die-cast metal threaded bands for connecting the hardware to the porcelain.

This method of construction, it is

Third Rail Insulator Manufactured by the Railway & Industrial Engineering Co.

claimed, has a distinct advantage in that the intimate bond produced by die-cast metal exerts an even pressure on the porcelain and resists the vibration existing in craneways and railway beds.

Portable Electric Drill

A NEW ¼-in. portable electric drill designated as No. 414, has recently been developed by the Millers Falls Co., Millers Falls, Mass. This drill is operated by a universal motor that can be furnished for either 110 or 220 volts, alternating or direct current. The motor speed is 1,800 r.p.m. at no-load and the capacity of the drill, which weighs 5½ lb., is said to be ¼ in. in steel, $\frac{7}{16}$ in. in cast iron, and ⅜ in. in wood.

The pigtail brushes can easily be replaced without taking the tool apart. An armored attachment plug is connected to 8 ft. of high-grade rubber-covered cord and an automatic switch which is mounted in the handle of the drill con-

Millers Falls ¼-in. portable electric drill

trols the motor, whose armature turns on ball bearings. The drill is fitted with a Jacobs heavy-duty chuck, heat-treated alloy steel gears, and a ball thrust bearing on the spindle.

Uni-Pull Belt Drive

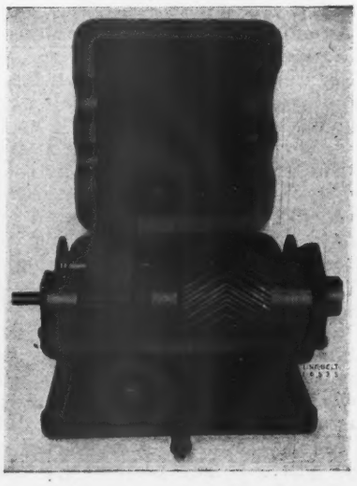
ANNOUNCEMENT has been made by the Rockwood Manufacturing Co., Indianapolis, Ind., of the Uni-Pull as its latest development in belt drives. It is claimed that this drive gives a marked improvement in operating efficiency over fixed-center belt drives, that it is particularly well adapted to close pulley centers, and that the drive operates at all times with uniform tension, uniform pull, and uniform speed.

Briefly, the Uni-Pull drive consists of a Rockwood pulley and a motor, so mounted that gravity, due to the weight of the motor, maintains the belt under a predetermined tension to meet the power requirements of the installation. This unit is shown driving a hammer mill on page 446. In tests conducted by the manufacturer, belts are being run at centers so close that the pulleys almost touch; in one installation an ordinary lead pencil could not be inserted between the pulleys, it is stated.

Herringbone Speed Reducer

DEVELOPMENT of a new line of herringbone speed reducers has been announced by the Link-Belt Co., 300 W. Pershing Road, Chicago, Ill. These reducers are made in three types and a variety of sizes and ratings. All gears are generated by the Sykes

Type D Heavy-Duty, Double-Reduction Link-Belt Speed Reducer with Sykes Herringbone Gears

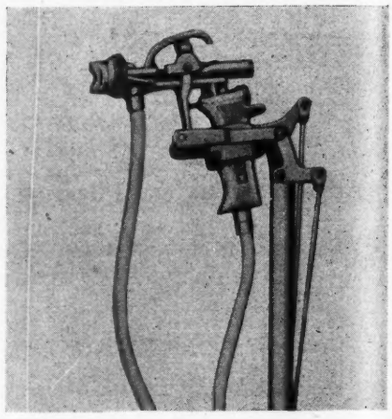


method which gives a continuous herringbone tooth.

The Type S reducer is a single-reduction, heavy-duty unit made in ratios up to 10:1 and the various sizes rated to deliver from 0.0252 to 2.77 hp. per revolution of the low-speed shaft. Type D is a double-reduction, heavy-duty unit made in ratios from 10:1 up to 80:1, with a low-speed output from 0.30 to 4 hp. per revolution. The type D unit is shown in an accompanying illustration. Type DS is a double-reduction unit designed for light service; this unit may be obtained in ratios from 11:1 up to 130:1 and rated to give 0.06 to 0.24 hp. per revolution on the low-speed shaft.

Paint Spray Equipment

A PAINT spray gun handle has been developed by the Alexander Milburn Co., Baltimore, Md. Use of this handle facilities the painting of ceilings, high



Milburn Spray Gun Extension Handle

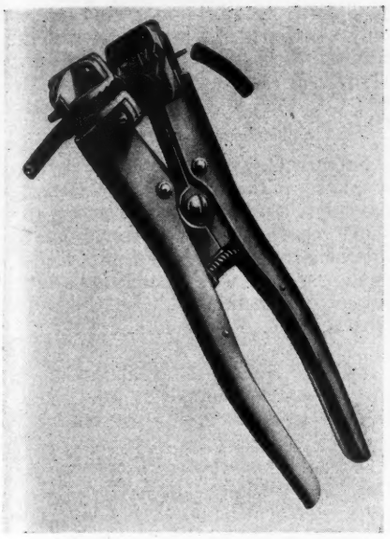
walls, ship sides, tanks, freight cars, and other high surfaces. The handle grips the standard Milburn gun, which, while in use, can be swiveled to any desired angle, it is stated.

The extension is ordinarily 8 ft. in length, although any size can be furnished. A slight pull on the operating handle of the extension simultaneously operates both the air and paint valves on the spray gun.

Wire Stripper

MARKETING of the E-Z wire stripper has been announced by the Pyramid Products Co., 2311 South State St., Chicago, Ill. This device, which is shown in the accompanying illustration, is hand-operated and is adaptable for use on any size of wire from 10 to 20 gage.

It is operated in the same way as a pair of pliers and will strip from ⅛ to 1 in. of insulation at a time. V-shaped notches guide the wire. The insulation is cut and removed in one opera-



E-Z Wire Stripper Manufactured by Pyramid Products Co.

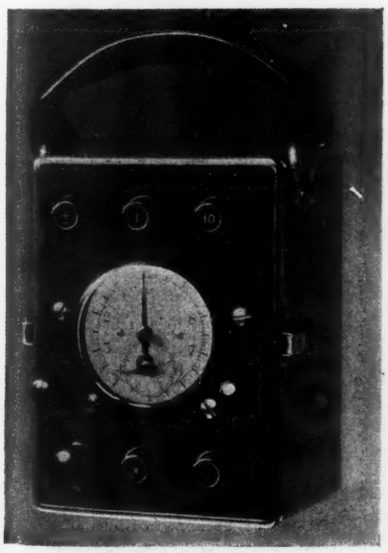
tion of the tool. It is claimed that the insulation can be removed from 1 ft. of wire in less than a minute. It is also said that when used properly there is no danger of nicking the wire when removing the insulation.

Portable Watt-Hour Meter

A NEW Type OB portable standard watt-hour meter has recently been placed on the market by the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Several advantages are claimed for the new meter, the outstanding one being the compensation for temperature errors at both unity power factor and low power factor. This compensation is claimed to be inherently permanent for both the electromagnets and the permanent magnets and does not depend on the movement of mechanical parts with the variation in temperature.

New Westinghouse Portable Standard Watt-Hour Meter



The accuracy and the decrease in size and weight of this meter are also important features. The micrometer adjustments have been simplified and the electromagnets are of the one-piece OB type. A zero reset is provided by which both pointers can be set on zero. Potential settings are changed by means of a small switch, and three current binding posts are used, so that the meter may be connected for either 1 or 10 amp. capacity.

Motor and Generator Brushes

A NEW metal and semi-metal brush material has recently been put on the market by the Keystone Carbon Co., Emporium, Pa. This metal brush material is said to be a composition of pure copper and graphite obtainable in a very wide range of proportions, which makes it available for all metal brush applications from the largest rotary converter to the smallest motors.

It is also stated that a method has been perfected by which all shunts are inserted into and processed with the raw material, and thus become an integral part of the brush.

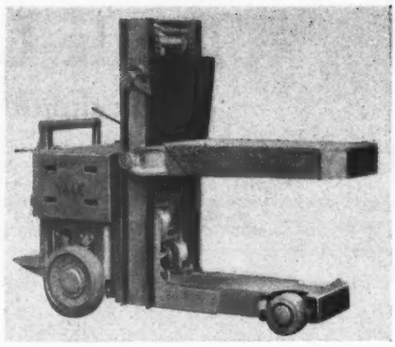
High-Lift Truck

THE Yale Model K25, three-ton high-lift, elevating truck has been added to the line of the Yale & Towne Manufacturing Co., Stamford, Conn. The backbone of the framework consists of a ½-in. thick gusset plate, which extends from the forward end of the truck to the small trailing wheels. The upright channels or platform roller guides are attached to this gusset plate by ¾-in. rivets and strips of steel welded to both sides of the vertical channels to form a pocket or guide.

The elevating platform is raised and lowered through a 1½-in. Diamond roller chain, passing over a power-driven sprocket at the bottom and an idler sprocket at the top. Hyatt heavy-duty roller bearings are employed in the idler sprocket and the shifts of the lower sheaves run in a bath of oil, which also serves to lubricate the spur-gear reduction unit. The two ends of the roller chain are attached to the platform through a spring take-up device, which will automatically adjust itself as the chain wears.

The hoisting motor is connected to the spur-gear pinion through a spring ratchet, so arranged that a positive drive is obtained when raising the elevating platform. A speed of 7½ ft. per minute is obtained when lifting a full load, and a speed of 19 ft. per minute when raising the empty platform. The lowering speed is 19 ft. per minute, loaded or empty.

The elevating platform of the truck is supported in the horizontal position by four rollers, bearing on the inside of the flanges of the vertical ship channels. Hyatt heavy-duty roller bearings are used in this case and a hardened steel thrust washer takes whatever end thrust may occur when lifting loads that



Three-Ton, Type K25, High-Lift Truck Made by the Yale & Towne Manufacturing Co.

are not placed on the center line of the platform.

The platform members are heavy steel castings, having large diameter bosses to support the platform roller pins. The platform has an over-all width of 27 in., a height of 11 in. and a length of 54 in. A four-wheel steering arrangement allows a turning radius of 96 in. at the outside edge of the truck.

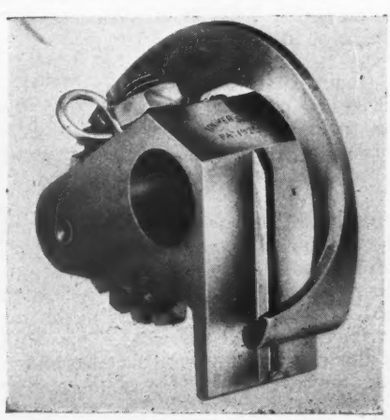
Commutator Brush Holder

ANNOUNCEMENT has been made by the Electric Accessories Co., 310 York Ave., Philadelphia, Pa., of its universal full-reaction brush holders for carbon brushes. It is claimed that this reaction-type holder, in addition to its advantages in commutation, allows a latitude in the width and thickness of bushes that permits the use of one type of brush on several motors.

As may be noted from the accompanying illustration, the design of the holder prevents the brushes from moving sideways on uneven commutators or shifting or moving in the holder due to side oscillation of the armature. It also prevents the brushes from wearing unevenly.

The fact that there is no guard around the brushes will, it is claimed, minimize the likelihood of the brushes sticking or wedging. These holders are made in five sizes. Special mountings can be furnished for adapting the holders to various types of machines.

Universal Full-Reaction Brush Holders



Trade Literature

you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

MECHANICAL RUBBER GOODS — Catalog 20 covers the Pioneer line of rubber belting, hose, packing, and other kinds of mechanical rubber goods.—Pioneer Rubber Mills, 345-53 Sacramento St., San Francisco, Calif.

ROLLER CHAIN—A folder illustrates and discusses the application of Diamond roller chain in power transmission.—The Diamond Chain & Mfg. Co., Indianapolis, Ind.

DRAG SCRAPER—Booklet 666 describes, gives specifications, and illustrates a number of applications of the Link-Belt Power Hoe (an improved drag scraper) for handling coal and other loose materials around industrial plants.—Link-Belt Co., 910 So. Michigan Ave., Chicago, Ill.

ELEVATORS AND CONVEYORS—Book 575 devotes 96 pages to a description and illustrations of applications of various types of Link-Belt elevators and conveyors.—Link-Belt Co., 910 So. Michigan Ave., Chicago, Ill.

SYNCHRONOUS MOTORS—Circular 500 discusses the flywheel effect recommendations for ammonia and carbon-dioxide compressors based on the use of the Ideal synchronous motor drive with flywheel-tpye rotors.—The Ideal Electric & Manufacturing Co., Mansfield, Ohio.

UNIT HEATERS — Bulletin entitled. "Cost of Heating and Ventilating Goes Down," describes the Bailey Thermo-Unit for heating and ventilating industrial plants.—Bailey Mfg. Co., Milwaukee, Wis.

BLOWERS AND EXHAUSTERS—Catalog 110 describes the motor and pulley driven types of Uniblade blowers and exhausters for constant and variable speed operation. — Autovent Fan & Blower Co., 730-738 W. Monroe St.. Chicago, Ill.

GROUNDOMETERS — Bulletin 77 describes a portable meter designed for measuring the resistance of ground electrodes. This is made in three types.—Groundulet Co., Newark, N. J.

BEARING METAL—A revised edition of the Magnolia Metal Bearing Book contains 96 pages of practical data, suggestions and instructions on the selection and preparation of bearing metal for various industrial services. This book is illustrated with several sketches showing improved methods of arranging shells for babbitting, the proper proportioning and clearances of bearings, and various arrangements of oil grooves.—Magnolia Metal Co., 75 West St., New York, N. Y.

SLEEVING — A card carries samples and quotes prices on various types of M-R varnish - saturated sleeving.—Mitchell-Rand Mfg. Co., 18 Vesey St., New York, N. Y.

GEARS—A circular illustrates and describes the addition of a line of cast and cut-tooth gears and speed reducers. —Gear Division, Stephens-Adamson Mfg. Co., Aurora, Ill.

FIBER PULLEYS — Circulars describe the line of compressed spruce fiber pulleys and give dimensions and prices of units carried in stock. — Compressed Spruce Products Co., Inc., West Orange, N. J.

SPEED REDUCERS—Catalog 99 covers the line of D. O. James speed reducers and cut gears together with over 50 pages of general engineering data.—D. O. James Mfg. Co., 1114 W. Monroe St., Chicago, Ill.

MATERIAL-HANDLING EQUIPMENT—A booklet entitled, "Jacklift and Stacker Practice," illustrates the numerous applications of the Lewis-Shepard handlift truck and the stacking or tiering machine.—Lewis-Shepard Co., Watertown Station, Boston, Mass.

TEMPERATURE REGULATORS — A 52-page catalog describes the various types of Powers temperature regulators, their application to shop and office, the fuel-saving advantages claimed, and describes a number of installations.—The Powers Regulator Co., 2720 Greenview Ave., Chicago, Ill.

HERRINGBONE GEARS — Bulletin B illustrates and describes a number of interesting applications of Fawcus cut-tooth herringbone gears and pinions.—Fawcus Machine Co., Pittsburgh, Pa.

UNIT HEATERS — Catalog 466 discusses the methods recommended for industrial heating by the use of the various types of Buffalo unit heaters.—Buffalo Forge Co., Buffalo, N. Y.

SHOCK ABSORBER—A recent bulletin illustrates the construction and describes the new Thompson Shock Absorber for use in connection with lighting equipment in industrial plants to prevent lamp spoilage from vibration. This unit has only four parts and may be used in connection with the Thompson Lowering Hanger or alone.—The Thompson Electric Co., 1438 W. Ninth St., Cleveland, Ohio.

SILENT CHAIN—"A Chain of Testimonials," is the title of a booklet issued recently. It contains interesting personal reports from men responsible for the efficient operation of plant equipment, together with photographs of the drives in question.—Morse Chain Co., Ithaca, N. Y.

SAFETY SWITCHES —Catalog No. 17 illustrates the complete line of TV safety switches with accompanying tables of sizes and capacities.—The Trumbull-Vanderpoel Electric Mfg. Co., Inc., Bantam, Conn.

ELECTRIC FURNACES—A circular illustrates the operation of the Ajax-Northrup metal-melting furnaces.—Ajax Electrothermic Corp., Trenton, N. J.

POWER TRANSMISSION — A recent issue of *The Labor Saver*, distributed monthly by this company, describes the construction and operation, illustrates applications, and gives engineering data on the JFS variable speed transmission and the S-A Speeducer spur-gear speed reducer.—Stephens-Adamson Mfg. Co., Aurora, Ill.

GEARS —A new publication, circular 1579-E, contains the latest authentic data and technical information relative to the manufacture, design and construction of Micarta gears and pinions.—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

ARC WELDING —"Modern Manufacturing With A Stable Arc Welder" is the title of a 36-page booklet recently issued. This booklet outlines briefly the theory of the use of arc welding in production manufacturing. — The Lincoln Electric Co., Cleveland, Ohio.

CHAINS —The fourth edition of the AHSC Catalog contains 60 pages of data on the design, application, and lubrication of high-speed chains.—American High Speed Chain Co., Indianapolis, Ind.

SWITCHING EQUIPMENT —A 48-page bulletin No. 32-C, has been issued, illustrating and describing the high-tension switching and protective equipment manufactured by this company.—The Delta-Star Electric Co., Chicago, Ill.

GEARS—Catalog 47 lists the complete line of Boston gears together with charts and diagrams of value to the gear user.—Boston Gear Works Sales Co.. Norfolk Downs, Quincy, Mass.

BALL BEARINGS—A series of loose-leaf pages give the revised dimensions and load ratings of SKF products.—SKF Industries, Inc., 40 E. Thirty-fourth St., New York, N. Y.